Total Maximum Daily Load Development for the James River and Tributaries – Lower Piedmont Region

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ACKNOWLEDGEMENTS

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EXECUTIVE SUMMARY

Background and Applicable Standards

Two streams in Goochland County and one in Fluvanna County that drain into the James River were placed on the 2002 Section 303(d) report on Impaired Waters for violations of the fecal coliform standard. One stream in Powhatan County along with two segments of the James River were added to the 2004 Section 305 (b)/303(d) Water Quality Assessment Integrated Report. Elevated levels of fecal coliform bacteria recorded at VADEQ ambient water quality monitoring stations showed that these James River basin stream segments do not support the standards for primary contact recreational. As a result, TMDLs are required for these six stream segments in the Lower Piedmont Region.

Figures ES.1 and ES.2 provide a geographical representation of the James River sub-basin covered in this report. For the purposes of this report, all of these watersheds shall be referred to as the James River and Tributaries – Lower Piedmont Region. Table ES.1 lists for each impairment, the type of impairment, the VADEQ water quality monitoring station used for the impaired waters assessment, the initial year that the segment was listed in the Section 303(d) list, current miles affected in the 2004 listing, fecal coliform violation rates in Virginia's *2002 Section 303(d) Report on Impaired Waters* and the *2004 Section 305(b)/303(d) Water Quality Assessment Integrated Report*, and the location of listing. Each of the six segments is in violation of the state standards for fecal coliform, specifically e.coli.

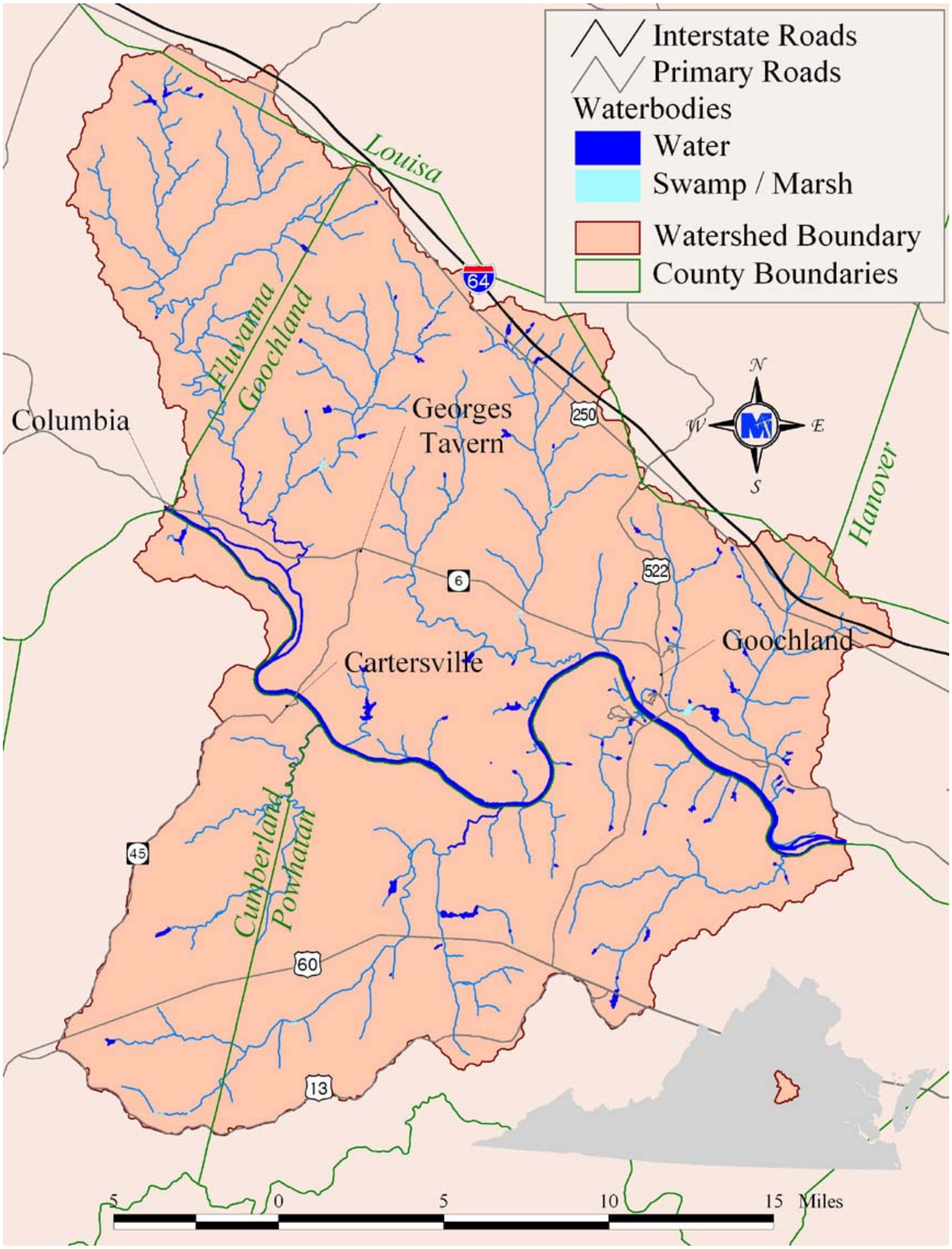

Figure ES. 1 Location of the watershed for the James River and Tributaries– Lower Piedmont Region.

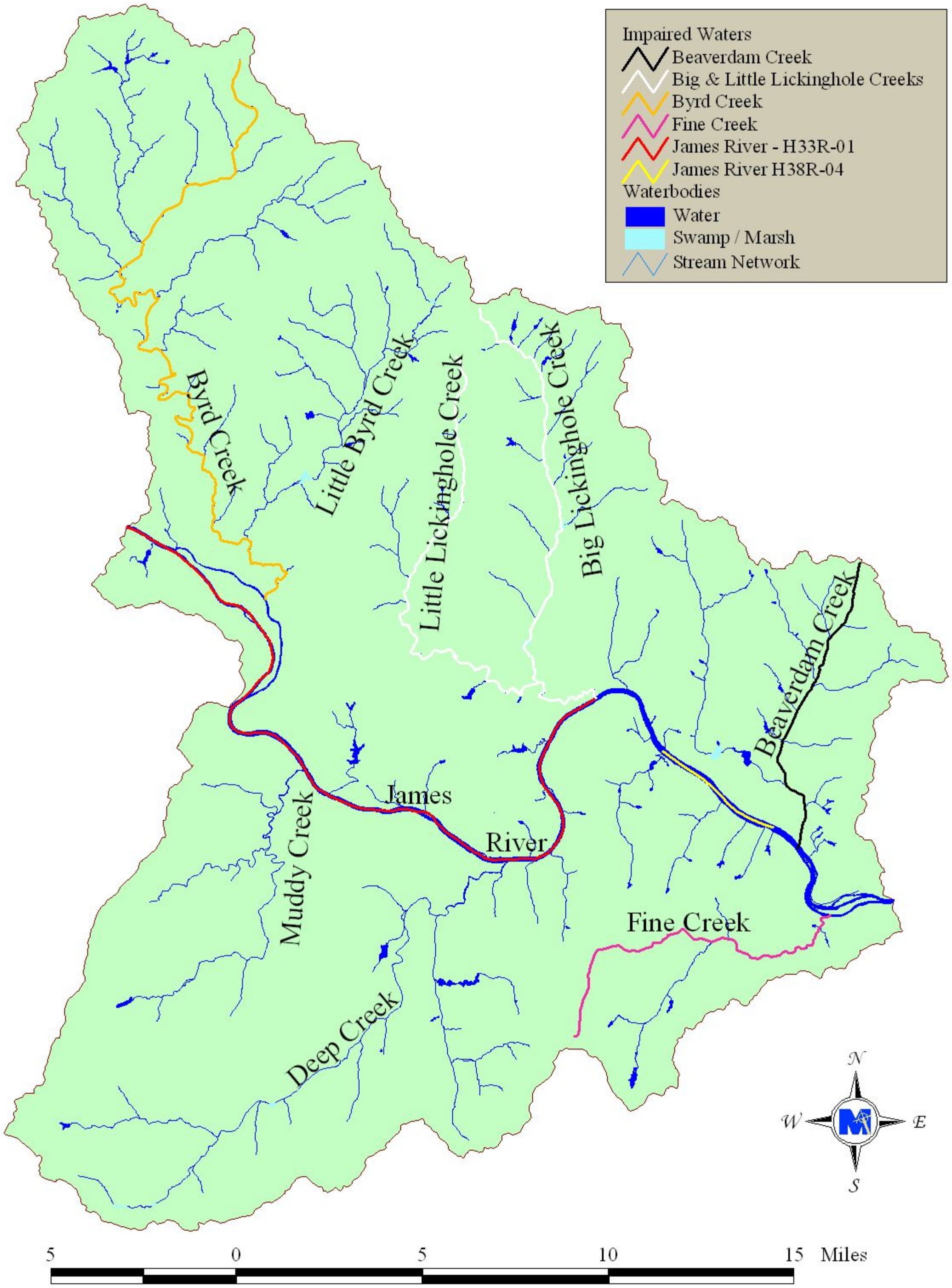

Figure ES. 2 Impaired stream segments in the James River and Tributaries–Lower Piedmont Region watershed.

Table ES. 1. Fecal coliform impairments on *2004 Section 305(b)/303(d) Water Quality Integrated Report* within the James River and Tributaries – Lower Piedmont Region.

Stream Name, HUP	Listing Station ID	Initial Listing	Miles Affected	2002 303(d) List FC Violation Rate	2004 303(d) List FC Violation Rate	Location
Byrd Creek, H34R-01	2BYR003.35	2002	25.97	3/27	3/21	Segment includes all of Byrd Creek from its headwaters to its confluence with Little River
Big Lickinghole Creek/Little Lickinghole Creek, H37R-01	2BLG002.60	2002	29.54	3/27	6/20	Segment includes the main stems of Big Lickinghole Creek and Little Lickinghole Creek
Fine Creek, H38R-01	2FIN000.81	2004	10.34	N/A	5/31	Segment includes all of Fine Creek from its headwaters to the confluence with the James River
Beaverdam Creek, H38R-03	2BDC000.79	2004	8.73	N/A	4/21	Segment includes all of Beaverdam Creek
James River, H38R-04	2JMS140.00	2004	3.64	N/A	2/10	Segment includes the James River from the confluence of Mohawk Creek downstream to river mile 137.
James River, H33R-01	2JMS157.28	2004	22.87	N/A	4/35	Segment includes the James River from the Rivanna River to Big Lickinghole Creek

TMDL Endpoint and Water Quality Assessment

Applicable Water Quality Standards

According to Virginia's State Water Control Board *Water Quality Standards* (9 VAC 25-260-5), the term ‘water quality standards’ means "…provisions of state or federal law which consist of a designated use or uses for the waters of the Commonwealth and water quality criteria for such waters based upon such uses. Water quality standards are to protect the public health or welfare, enhance the quality of water and serve the purposes of the Sate Water Control Law and the federal Clean Water Act."

Section 9 VAC 25-260-170 is the applicable water quality criteria for fecal coliform impairments in the James River and Tributaries – Lower Piedmont Region and reads as follows:

> *A. In surface waters, except shellfish waters and certain waters identified in subsection B of this section, the following criteria shall apply to protect primary contact recreational uses:*
>
> *1. Fecal coliform bacteria shall not exceed a geometric mean of 200 fecal coliform bacteria per 100 ml of water for two or more samples over a calendar month nor shall more than 10% of the total samples taken during any calendar month exceed 400 fecal coliform bacteria per 100 ml of water. This criterion shall not apply for a sampling station after the bacterial indicators described in subdivision 2 of this subsection have a minimum of 12 data points or after June 30, 2008, whichever comes first.*
>
> *2. E. coli and enterococci bacteria per 100 ml of water shall not exceed the following:*

	Geometric Mean[1]	*Single Sample Maximum*[2]
Freshwater[3]		
E. coli	*126*	*235*
Saltwater and Transition Zone[3]		
enterococci	*35*	*104*

[1] For two or more samples taken during any calendar month.
[2] No single sample maximum for *enterococci* and *E. coli* shall exceed a 75% upper one-sided confidence limit based on a site-specific log standard deviation. If site data are insufficient to establish a site-specific log standard deviation, then 0.4 shall be used as the log standard deviation in freshwater and 0.7 shall be as the log standard deviation in saltwater and transition zone. Values shown are based on a log standard deviation of 0.4 in freshwater and 0.7 in saltwater.
[3] See 9 VAC 25-260-140 C for freshwater and transition zone delineation.

Targeted Source of Impairment - Fecal Coliform

Potential sources of fecal coliform include both point source and nonpoint source (NPS) contributions. Nonpoint sources include: wildlife, grazing livestock, land application of manure and biosolids, urban/residential runoff, failed and malfunctioning septic systems, and uncontrolled discharges (straight pipes). Fecal bacteria TMDLs in the Commonwealth of Virginia are developed using the *E. coli* standard. For this TMDL development, the in-stream *E. coli* target was a geometric mean not exceeding 126-cfu/100 mL and a single sample maximum of 235-cfu/100 mL. A translator developed by VADEQ was used to convert fecal coliform values to *E. coli* values.

Fecal coliform detection and analysis is further discussed in section 2.4 entitled "Discussion of In-stream Water Quality".

Modeling Procedures – Linking the Sources to the Endpoint

Establishing the relationship between in-stream water quality and the source loadings is a critical component of TMDL development. It allows for the evaluation of management options that will achieve the desired water quality endpoint. In the development of TMDLs in the James River – Lower Piedmont Region, the relationship was defined through computer modeling based on data collected throughout the watersheds. Monitored flow and water quality data were then used to verify that the relationships developed through modeling were accurate. There are six basic steps in the development and use of a water quality model: model selection, source assessment, selection of a representative modeling period, model calibration, model validation, and model simulation.

Model selection involves identifying an approved model that is capable of simulating the pollutants of interest with the available data. Source assessment involves identifying and quantifying the potential sources of pollutants in the watershed. Selection of a representative period involves the identification of a time period that accounts for critical conditions associated with all potential sources within the watershed. Calibration is the process of comparing modeled data to observed data and making appropriate adjustments to model parameters to minimize the error between observed and simulated events. Validation is the process of comparing modeled data to observed data during a period other than that used for calibration, with the intent of assessing the capability of the model in hydrologic conditions other than those used during calibration. During validation, no adjustments are made to model parameters. Once a suitable model is constructed, the model is then used to predict the effects of current loadings and potential management practices on water quality. In Chapter 4, the selection of modeling tools, source assessment, selection of a representative period, calibration/validation, and model application are discussed.

Existing Conditions

Fecal Coliform

Wildlife populations, the rate of failure of septic systems, domestic pet populations, and numbers of livestock impairments in the two segments of the James River and four tributaries are examples of land-based nonpoint sources used to calculate fecal coliform loads. Also represented in the model were direct nonpoint sources of uncontrolled discharges, direct deposition by wildlife, and direct deposition by livestock. Contributions from all of these sources were updated to 2006 conditions to establish existing conditions for the watershed. The calibrated HSPF model predicted violations of both the instantaneous and geometric mean standards throughout the impaired watersheds when the model was run using existing conditions.

Load Allocation Scenarios

The next step in the bacteria TMDL process was to reduce the various source loads within the model to levels that would result in attainment of the water quality standards. Because Virginia's *E. coli* standard does not permit any exceedances of the standard, modeling was conducted for a target value of 0% exceedance of the geometric mean standard and 0% exceedance of the single sample maximum *E. coli* standard. Scenarios were evaluated to predict the effects of different combinations of source reductions on final in-stream water quality. The final TMDL loads are shown in Tables 5.1 through 5.6.

The following are the recommended load allocation scenarios for the six stream segments in order to obtain no (or as specifically noted) violations of the standards:

Byrd Creek

- 100% reduction in all anthropogenic direct sources;
- 99% reductions in nonpoint pasture/livestock access/cropland loads;
- 99%reduction in residential and urban land-based loads;
- 71% reductions in wildlife land-based and direct loads

Big & Little Lickinghole Creeks

- 100% reduction in all anthropogenic direct sources;
- 99% reductions in nonpoint pasture/livestock access/cropland loads;
- 99% reduction in residential and urban land-based loads;
- 53.5% reduction in wildlife land-based and direct loads

Beaverdam Creek

- 100% reduction in all anthropogenic direct sources;
- 99% reductions in nonpoint pasture/livestock access/cropland loads;
- 99% reduction in residential and urban land-based loads;
- 77% reduction in wildlife land-based and direct loads

Fine Creek

- 100% reduction in all anthropogenic direct sources;
- 99% reductions in nonpoint pasture/livestock access/cropland loads;
- 99% reduction in residential and urban land0based loads;
- 53% reduction in wildlife land-based and direct loads

Upper James River (H33R-01)

- 90%reductions in all anthropogenic direct sources;
- 90%reductions in nonpoint pasture/livestock access/cropland loads;
- 90% reduction in residential and urban land-based loads;
- 0% reduction in wildlife land-based and direct loads

Lower James River (H38R-04)

- 93% reduction in all anthropogenic direct sources;
- 93% reductions in nonpoint pasture/livestock access/cropland loads;
- 93% reduction in residential and urban-based loads
- 0% reduction in wildlife land-based and direct loads

The final TMDL loads are shown in Table ES. 2 included below. It can be observed from this Table ES.2 that future growth load in the waste load allocation for Beaverdam Creek is relatively higher than future growth for the rest of the impairments. This is due to the current high effluent from point sources existing within Beaverdam watershed. Expected growth in bacteria loads from point sources is a function of existing loads from point sources within the watershed.

Table ES. 2 Average annual *E. coli* (cfu/year) modeled after TMDL allocation in the James River Tributaries – Lower Piedmont Region.

Impairment	TMDL Standard	WLA (cfu/year)	LA (cfu/year)	MOS	TMDL (cfu/year)
Byrd Creek	*E. coli*	1.08E+11	9.51E+12		9.62E+12
VAG404239		*1.74E+09*			
VAG404240		*1.74E+09*			
VAG406343		*1.74E+09*			
VAG406344		*1.74E+09*			
VAG406345		*1.74E+09*			
VAG406346		*1.74E+09*			
VAG406347		*1.74E+09*			
Future Growth		*9.57E+10*			
Big & Little Lickinghole Creek	*E. coli*	7.94E+10	7.90E+12		7.98E+12
Future Growth		*7.94E+10*			
Beaverdam Creek	*E. coli*	3.13E+12	5.01E+12		8.14E+12
VA0020681		*3.76E+11*			
VA0006149		*1.04E+11*			
VA0023108		*3.48E+10*			
VA0063037		*6.96E+09*			
Future Growth		*2.61E+12*			
Fine Creek	*E. coli*	3.66E+10	3.63E+12		3.67E+12
Future Growth		*3.66E+10*			
James River (upper, H33R-01)	*E. coli*	3.54E+11	3.92E+15	*Implicit*	3.92E+15
VA0062731		*2.17E+10*			
VA0088382		*3.48E+10*			
VAG404239		*1.74E+09*			
VAG404240		*1.74E+09*			
VAG406343		*1.74E+09*			
VAG406344		*1.74E+09*			
VAG406345		*1.74E+09*			
VAG406346		*1.74E+09*			
Future Growth		*2.83E+11*			
James River (lower, H38R-04)	*E. coli*	7.92E+12	3.91E+15		3.91E+15
VA0062731		*2.17E+10*			
VA0088382		*3.48E+10*			
VA0020656		*1.57E+11*			
VA0020699		*8.09E+11*			
VA0020702		*3.41E+11*			
VAG404239		*1.74E+09*			
VAG404240		*1.74E+09*			
VAG406343		*1.74E+09*			
VAG406344		*1.74E+09*			
VAG406345		*1.74E+09*			
VAG406346		*1.74E+09*			
VAG406347		*1.74E+09*			
VAG404226		*1.74E+09*			
Future Growth		*6.54E+12*			

Implementation

The goal of the TMDL program is to establish a three-step path that will lead to attainment of water quality standards. The first step in this process is to develop TMDLs that will result in meeting water quality standards. The second step is to develop a TMDL implementation plan (IP). The final step is to implement the TMDL IP and to monitor stream water quality to determine if water quality standards are being attained.

While section 303(d) of the Clean Water Act (CWA) and current United States Environmental Protection Agency (EPA) regulations do not require the development of TMDL implementation plans as part of the TMDL process, they do require reasonable assurance that the load and wasteload allocations can and will be implemented. Once a TMDL IP is developed, VADEQ will take the plan to the State Water Control Board (SWCB) for approval for implementing the pollutant allocations and reductions contained in the TMDL. Also, VADEQ will request SWCB authorization to incorporate the TMDL implementation plan into the appropriate waterbody. With successful completion of implementation plans, Virginia begins the process of restoring impaired waters and enhancing the value of this important resource.

In general, Virginia intends for the required reductions to be implemented in an iterative process that first addresses those sources with the largest impact on water quality. For example, to address the bacteria TMDL, reducing the human bacteria loading from straight pipes and failing septic systems should be a primary implementation focus because of the health implications. This component could be implemented through education on septic tank pump-outs as well as a septic system installation/repair program. Livestock exclusion from streams has been shown to be very effective in lowering bacteria concentrations in streams, both by reducing the direct cattle deposits and by providing additional riparian buffers. Reduced trampling and soil shear on streambanks by livestock has been shown to reduce bank erosion.

In some streams for which TMDLs have been developed, factors may prevent the stream from attaining its designated use. In order for a stream to be assigned a new designated use, or a subcategory of a use, the current designated use must be removed. The state must also demonstrate that attaining the designated use is not feasible. Information is collected through a special study called a Use Attainability Analysis (UAA). All site-specific criteria or designated use changes must be adopted by the SWCB as amendments to the water quality standards regulations. During the regulatory process, watershed stakeholders and other interested citizens as well as EPA will be able to provide comment during this process.

Public Participation

Public participation during TMDL development for the James River and Tributaries – Lower Piedmont Region was strongly encouraged; a summary of the meetings is presented in Table ES.3. The first public meeting was held at the Goochland County Administration Building in Goochland, Virginia on July 19, 2006; 11 people attended, including 2 landowners, 1 consultant, and 8 agency representatives. The meeting was publicized by placing notices in the Virginia Register, electronic mail advertisement to all agencies.

Table ES. 3 Public participation during TMDL development for the James River and Tributaries – Lower Piedmont Region.

Date	Location	Attendance[1]	Type	Format
7/19/2006	Goochland County Admin. Building 1800 Sandy Hook Rd. Goochland, VA	11	First Public Meeting	Open to public at large
7/19/2006	Goochland County Admin. Building 1800 Sandy Hook Rd. Goochland, VA	10	First TAC Meeting	
1/31/2008	Goochland County Admin. Building 1800 Sandy Hook Rd. Goochland, VA	7	Final Public Meeting	Open to public at large
1/31/2008	Goochland County Admin. Building 1800 Sandy Hook Rd. Goochland, VA	12	Final TAC Meeting	

[1]The number of attendants is estimated from sign up sheets provided at each meeting. These numbers are known to underestimate the actual attendance.

The first Technical Advisory Committee (TAC) meeting also took place on July 19, 2006 in the Goochland County Administration Building in Goochland, Virginia. The meeting was attended by 10 people, including one consultant, and 9 agency representatives. The meeting was publicized by placing notices in the Virginia Register, electronic mail advertisement to all agencies.

The final public meeting was held at the Goochland County Administration Building in Goochland, Virginia on January 31, 2008; 7 people attended, including 1 landowners, 1 consultant, and 5 agency representatives. The meeting was publicized by placing notices in the Virginia Register, and electronic mail advertisement to all agencies. The final Technical Advisory Committee (TAC) meeting also took place on January 31, 2008 in the Goochland County Administration Building in Goochland, Virginia. The meeting was attended by 12 people, including 1 consultant, and 10 agency representatives. The meeting was publicized by placing notices in the Virginia Register, and electronic mail advertisement to all agencies.

Public participation during the implementation plan development process will include the formation of a stakeholders' committee as well as open public meetings. Public participation is critical to promote reasonable assurances that the implementation activities will occur. A stakeholders' committee will have the express purpose of formulating the TMDL Implementation Plan. The major stakeholders were identified during the development of this TMDL. The committee will consist of, but not be limited to, representatives from VADEQ, VADCR, and local governments. This committee will have the responsibility for identifying corrective actions that are founded in practicality, establishing a time line to insure expeditious implementation, and setting measurable goals and milestones for attaining water quality standards.

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1. INTRODUCTION

1.1 Background

The Clean Water Act (CWA) enacted in 1972 states that all U.S. streams, rivers, and lakes must meet certain water quality standards and also requires that states conduct monitoring to identify impaired waters or those that do not meet the standards. Through this mandatory program, the state of Virginia has found that many stream segments are polluted and do not meet state water quality standards for the protection of the five beneficial uses: recreational, aquatic life, wildlife, fishing/shellfish harvesting, and drinking.

When streams fail to meet the standards, both Section 303(d) of the CWA and the U.S. Environmental Protection Agency's (EPA) Water Quality Management and Planning Regulation (40 CFR Part 130) require that states develop a Total Maximum Daily Load (TMDL) for each pollutant violating the standard. A TMDL is a "pollution budget" for a stream. That is, it sets limits on the amount of pollution that a stream can tolerate and still maintain water quality standards. In order to develop a TMDL, background concentrations, point source loadings, and nonpoint source loadings are considered. A TMDL accounts for seasonal variations and must include a margin of safety (MOS). Through the TMDL process, states establish water-quality based controls to reduce pollution and meet water quality standards.

Once a TMDL is developed and approved by EPA, measures must be taken to reduce pollution levels in the stream. Virginia's 1997 Water Quality Monitoring, Information and Restoration Act (WQMIRA) states in section 62.1-44.19:7 that the "Board shall develop and implement a plan to achieve fully supporting status for impaired waters". The TMDL Implementation Plan (IP) describes control measures, which can include the use of better treatment technology and the installation of best management practices (BMPs), which should be implemented in a staged process.

The study area (Figure 1.1) within the current report is part of the James River (contained in USGS Hydrologic Unit Code 02080205) basin, which drains to the Chesapeake Bay.

The current group of stream impairments studied in this report contains segments of Byrd Creek, Big Lickinghole Creek and Little Lickinghole Creek, Fine Creek, Beaverdam Creek, and the James River, which include portions of Virginia's Fluvanna, Goochland, Louisa, Powhatan and Cumberland counties (Figure 1.2). The Virginia Department of Environmental Quality (VADEQ) has identified all of these segments as violating the fecal coliform standard. For the purposes of this report, all of these watersheds shall be referred to as the James River and Tributaries – Lower Piedmont Region.

Table 1.1 lists for each impairment, the type of impairment, the VADEQ water quality monitoring station used for the impaired waters assessment, the initial year that the segment was listed in the Section 303(d) list, current miles affected in the 2004 listing, fecal coliform violation rates in Virginia's *2002 Section 303(d) Report on Impaired Waters* and the *2004 Section 305(b)/303(d) Water Quality Assessment Integrated Report*, and the location of listing.

The Byrd Creek, Big Lickinghole Creek and Little Lickinghole Creek segments were placed on the *2002 Section 303(d) Report on Impaired Waters* for violations of the fecal coliform standard (Table 1.1). Fine Creek, Beaverdam Creek and the James River segments were added to the *2004 Section 305(b)/303(d) Water Quality Assessment Integrated Report*. Elevated levels of fecal coliform bacteria recorded at VADEQ ambient water quality monitoring stations showed that these James River basin stream segments do not support the primary contact recreation use.

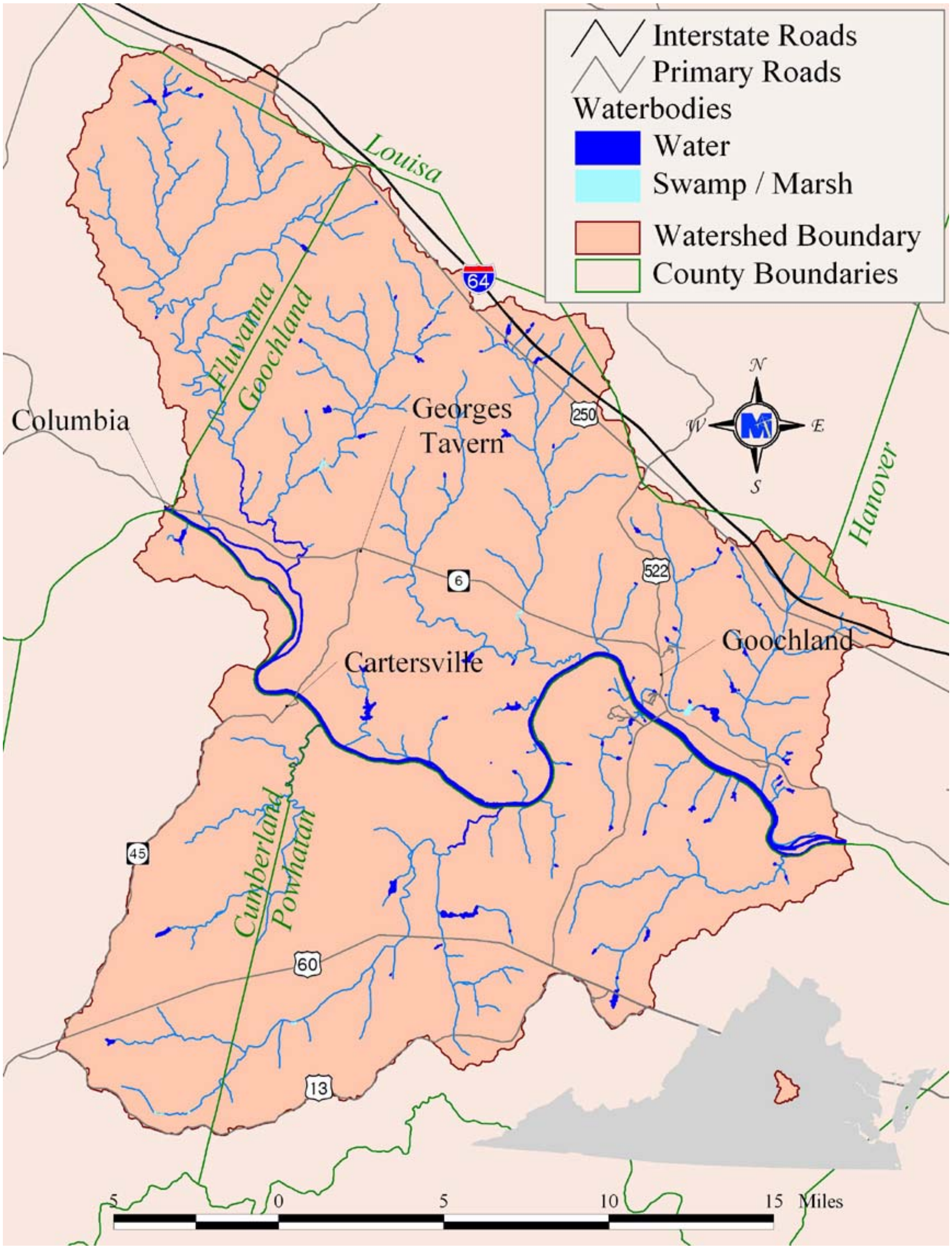

Figure 1.1 Location of the watershed for the James River and Tributaries– Lower Piedmont Region.

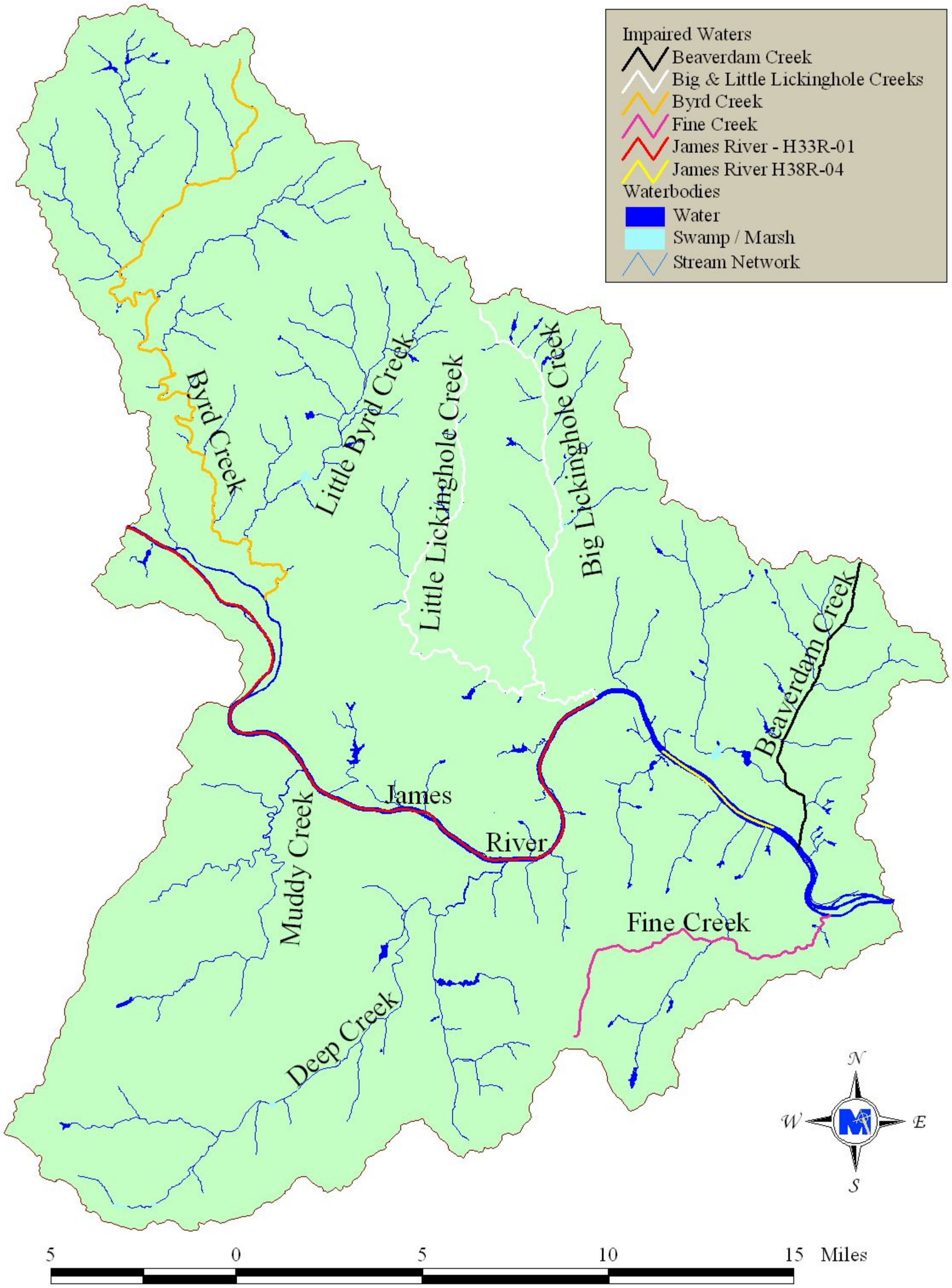

Figure 1.2 Impaired stream segments in the James River and Tributaries– Lower Piedmont Region watershed.

Table 1.1 Fecal coliform impairments on *2004 Section 305(b)/303(d) Water Quality Integrated Report* within the James River and Tributaries – Lower Piedmont Region.

Stream Name, HUP	Listing Station ID	Initial Listing	Miles Affected	2002 303(d) List FC Violation Rate	2004 303(d) List FC Violation Rate	Location
Byrd Creek, H34R-01	2BYR003.35	2002	25.97	3/27	3/21	Segment includes all of Byrd Creek from its headwaters to its confluence with Little River
Big Lickinghole Creek/Little Lickinghole Creek, H37R-01	2BLG002.60	2002	29.54	3/27	6/20	Segment includes the main stems of Big Lickinghole Creek and Little Lickinghole Creek
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Beaverdam Creek, H38R-03	2BDC000.79	2004	8.73	N/A	4/21	Segment includes all of Beaverdam Creek
James River, H38R-04	2JMS140.00	2004	3.64	N/A	2/10	Segment includes the James River from the confluence of Mohawk Creek downstream to river mile 137.
James River, H33R-01	2JMS157.28	2004	22.87	N/A	4/35	Segment includes the James River from the Rivanna River to Big Lickinghole Creek

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2. TMDL ENDPOINT AND WATER QUALITY ASSESSMENT

2.1 Applicable Water Quality Standards

According to Virginia's State Water Control Board *Water Quality Standards* (9 VAC 25-260-5), the term 'water quality standards' means "…provisions of state or federal law which consist of a designated use or uses for the waters of the Commonwealth and water quality criteria for such waters based upon such uses. Water quality standards are to protect the public health or welfare, enhance the quality of water and serve the purposes of the State Water Control Law and the federal Clean Water Act."

As stated in Virginia state law 9 VAC 25-260-10 (Designation of uses),

> *A. All state waters, including wetlands, are designated for the following uses: recreational uses, e.g., swimming and boating; the propagation and growth of a balanced, indigenous population of aquatic life, including game fish, which might reasonably be expected to inhabit them; wildlife; and the production of edible and marketable natural resources, e.g., fish and shellfish.*
>
> ♦
>
> *D. At a minimum, uses are deemed attainable if they can be achieved by the imposition of effluent limits required under §§301(b) and 306 of the Clean Water Act and cost-effective and reasonable best management practices for nonpoint source control.*

Section 9 VAC 25-260-170 is the applicable water quality criteria for fecal coliform impairments in the James River and Tributaries – Lower Piedmont Region and reads as follows:

> *A. In surface waters, except shellfish waters and certain waters identified in subsection B of this section, the following criteria shall apply to protect primary contact recreational uses:*
>
> *1. Fecal coliform bacteria shall not exceed a geometric mean of 200 fecal coliform bacteria per 100 ml of water for two or more samples over a calendar month nor shall more than 10% of the total samples taken during any calendar month exceed 400 fecal coliform bacteria per 100 ml of water. This criterion shall not apply for a sampling station after the bacterial indicators described in subdivision 2 of this subsection have a minimum of 12 data points or after June 30, 2008, whichever comes first.*

2. E. coli and enterococci bacteria per 100 ml of water shall not exceed the following:

	Geometric Mean[1]	*Single Sample Maximum*[2]
Freshwater[3]		
E. coli	*126*	*235*
Saltwater and Transition Zone[3]		
enterococci	*35*	*104*

[1] For two or more samples taken during any calendar month.
[2] No single sample maximum for *enterococci* and *E. coli* shall exceed a 75% upper one-sided confidence limit based on a site-specific log standard deviation. If site data are insufficient to establish a site-specific log standard deviation, then 0.4 shall be used as the log standard deviation in freshwater and 0.7 shall be as the log standard deviation in saltwater and transition zone. Values shown are based on a log standard deviation of 0.4 in freshwater and 0.7 in saltwater.
[3] See 9 VAC 25-260-140 C for freshwater and transition zone delineation.

2.2 Selection of a TMDL Endpoint.

The first step in developing a TMDL is the establishment of in-stream numeric endpoints that are used to evaluate the attainment of acceptable water quality. In-stream numeric endpoints, therefore, represent the water quality goals that are to be achieved by implementing the load reductions specified in the TMDL. For the James River and Tributaries – Lower Piedmont Region TMDL, the applicable endpoints and associated target values can be determined directly from the Virginia water quality regulations. In order to remove a waterbody from a state's list of impaired waters, the CWA requires compliance with that state's water quality standard. Since modeling provided simulated output of *E. coli* concentrations at 1-hour intervals, assessment of TMDLs was made using both the geometric mean standard of 126 cfu/100 ml and the instantaneous standard of 235 cfu/100 ml. Therefore, the in-stream *E. coli* targets for these TMDLs were a monthly geometric mean not exceeding 126 cfu/100 ml and a single sample not exceeding 235 cfu/100 ml.

2.3 Selection of a TMDL Critical Condition.

EPA regulations (40 CFR 130.7 (c)(1)) require that TMDLs take into account critical conditions for stream flow, loading, and water quality parameters. The intent of this requirement is to ensure that the water quality of the James River and Tributaries– Lower Piedmont Region is protected during times when it is most vulnerable.

Critical conditions are important because they describe the factors that combine to cause a violation of water quality standards and will help in identifying the actions that may have to be undertaken in order to meet water quality standards. Fecal bacteria sources within the James River and Tributaries – Lower Piedmont Region are attributed to both point and nonpoint sources. Critical conditions for waters impacted by land-based nonpoint sources generally occur during periods of wet weather and high surface runoff. In contrast, critical conditions for point source-dominated systems generally occur during low flow and low dilution conditions. Point sources, in this context also, include non-point sources that are not precipitation-driven (*e.g.*, fecal direct deposition to the stream).

A graphical analysis of fecal coliform concentrations and flow duration intervals showed that there was, in general, no obvious critical flow level. There were fewer violations of the standard during the highest 10 % of flow in most stations. However, fewer samples were collected in this range of flow more than any other range, which could explain the fewer violations during the highest flows. An example of such behavior is shown in Figure 2.1 for monitoring data at Fine Creek monitoring station 2-FIN000.8. The two James River stations (Figures C.5 and C.6 in Appendix C) exhibited different behavior where violations happened more frequently during high flows. This could be attributed to the fact that even during low flows, a large water body such as the James River has enough dilution capacity to handle bacteria loads coming in from point sources and direct non-point sources. The remainder of data for other monitoring stations are given in Appendix C.

Based on this analysis, a time period for calibration and validation of the model was chosen based on the overall distribution of wet and dry seasons (Section 4.5) in order to capture a wide range of hydrologic circumstances for all impaired streams in this study area. The resulting periods for calibration and validation for each impaired stream are also presented in Chapter 4.

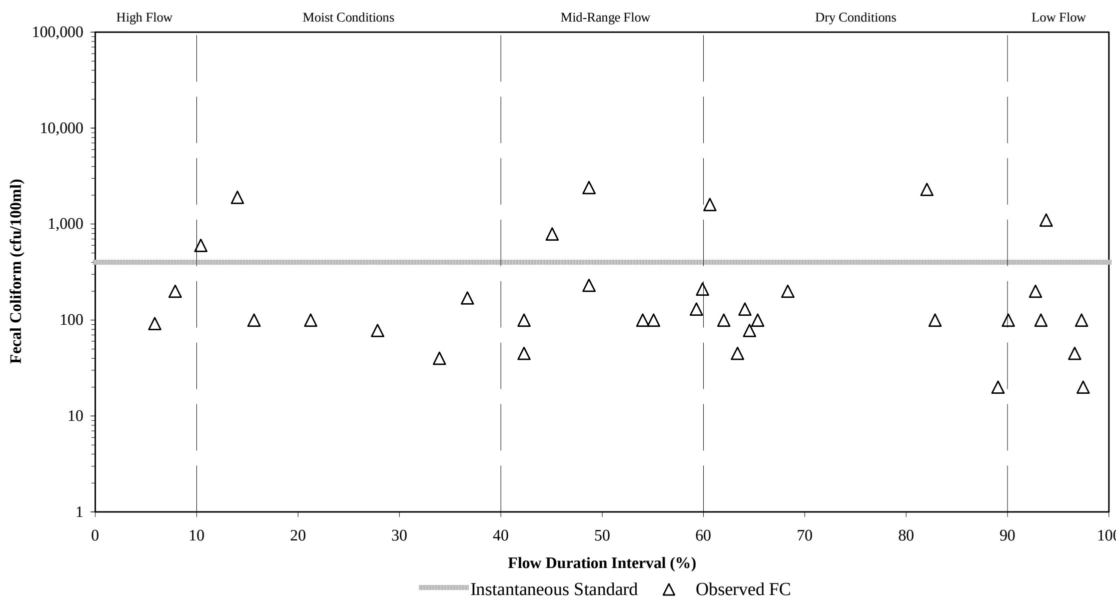

Figure 2.1 Relationship between fecal coliform concentrations (VADEQ Station 2-FIN00.81) and discharge (USGS Gaging Station #02036500) in the Fine Creek.

2.4 Discussion of In-stream Water Quality

This section provides an inventory and analysis of available observed in-stream fecal coliform monitoring data throughout the James River and Tributaries – Lower Piedmont Region. An examination of data from water quality stations used in the 303(d) assessment was performed and data collected during TMDL development were analyzed. Sources of data and pertinent results are discussed.

2.4.1 Inventory of Water Quality Monitoring Data

The primary sources of available water quality information are:

- Bacteria enumerations from ten VADEQ in-stream monitoring stations used for TMDL assessment with each having at least 12 samples collected. Many other VADEQ stations that started operating recently but do not yet have enough samples to be used in the analysis are alos reported here (Tables 2.1 and 2.2) ; and
- Bacteria enumerations and bacterial source tracking from six VADEQ in-stream monitoring stations analyzed during TMDL development.

2.4.1.1 Water Quality Monitoring for TMDL Assessment

Data from in-stream fecal coliform samples, collected from VADEQ monitoring stations (Figure 2.2), were analyzed from July 2003 through January 2006 and are included in the analysis. Samples were taken for the express purpose of determining compliance with the state instantaneous standard limiting concentrations to 400 cfu/100 mL or less. Therefore, as a matter of economy, samples showing fecal coliform concentrations below 100 cfu/100 ml or in excess of a specified cap (*e.g.*, 8,000 or 16,000 cfu/100 ml, depending on the laboratory procedures employed for the sample) were not further analyzed to determine the precise concentration of fecal coliform bacteria. The result is that reported concentrations of 100 cfu/100 ml most likely represent concentrations below 100 cfu/100 ml, and reported concentrations of 8,000 or 16,000 cfu/100 ml most likely represent concentrations in excess of these values. Tables 2.1 and 2.2 summarize the fecal coliform and *E*.coli samples collected at the in-stream monitoring stations used for TMDL assessment, respectively.

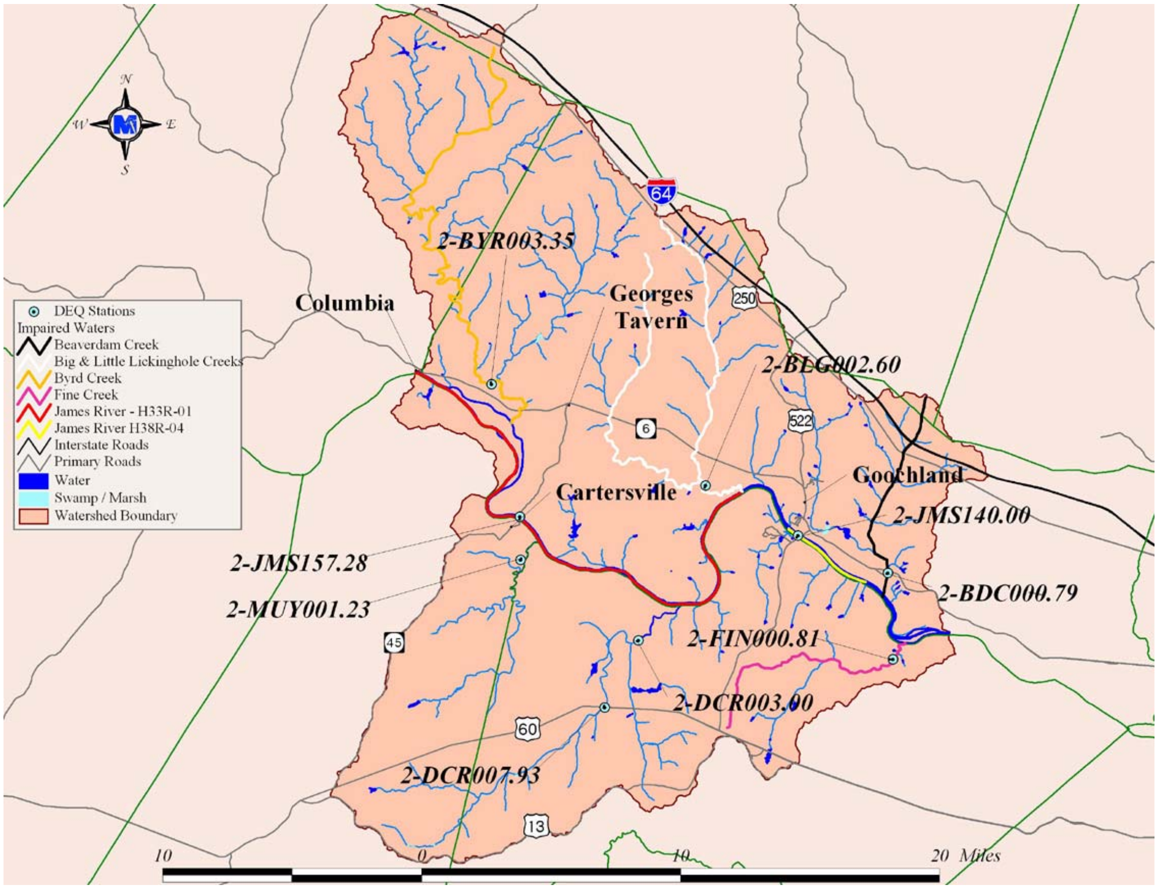

Figure 2.2 Location of VADEQ water quality monitoring stations used for TMDL assessment in the James River and Tributaries – Lower Piedmont Region.

Table 2.1 Summary of fecal coliform (cfu/100 ml) sampling conducted by VADEQ for period January 1980 through December 2005.

Stream Name	Station Id	Sampled Dates	Count	Minimum	Maximum	Mean	Median	Standard Deviation	Violation %
Beaverdam Creek	2-BDC000.79	7/94-4/01	35	20	9,200	632	130	1,741	17
Big Lickinghole Creek	2-BLG002.60	1/90 – 4/01	50	18	8,000	681	120	1,534	24
Big Lickinghole Creek	2-BLG011.41	4/05	1	75	75	NA	NA	NA	0
Byrd Creek	2-BYR003.35	7/94 – 4/01	35	20	9,200	664	100	1,691	23
Deep Creek	2-DCR003.00	8/90 – 4/01	52	18	5,100	401	100	967	13
Deep Creek	2-DCR007.93	5/01 – 6/03	12	100	400	133	100	89	0
Fine Creek	2-FIN000.81	8/90 – 12/05	79	20	8,000	433	100	1,060	16
James River	2-JMS140.00	7/83 – 5/03	19	4	8,000	585	100	1,819	11
James River	2-JMS157.28	1/80 – 2/01	225	8	16,000	348	100	534	10
Little Byrd Creek	2-LTP002.69	5/02	1	400	400	NA	NA	NA	0
Middle Fork Kent Branch	2-MFK002.21	4/03	1	400	400	NA	NA	NA	0
Muddy Creek	2-MUY001.23	5/01 – 6/03	12	100	5,600	650	150	1,566	17
Ransome Creek	2-RSM001.88	4/05	1	25	25	NA	NA	NA	0
Stegers Creek	2-STG000.21	7/91 – 8/96	2	100	100	100	100	0	0
Stegers Creek	2-STG000.91	7/91 – 8/96	2	100	100	100	100	0	0
UT to Bonbrook Creek	2-XLX000.20	8/89	1	2	2	NA	NA	NA	0
UT to Little Lickinghole Creek	2-XVX000.62	3/04	1	25	25	NA	NA	NA	0
UT to Sallee Creek	2-XLZ000.62	7/89	1	18	18	NA	NA	NA	0
UT to Sallee Creek	2-XLZ000.82	7/89	1	170	170	NA	NA	NA	0

Table 2.2 Summary of *E. coli* (cfu/100 ml) sampling conducted by VADEQ for period July 2003 through December 2005.

Stream Name	Station Id	Sampled Dates	Count	Minimum	Maximum	Mean	Median	Standard Deviation	Violation %
Deep Creek	2-DCR003.00	5/05 – 11/05	4	25	180	76	50	73	0
Deep Creek	2-DCR013.89	8/03 – 3/05	11	25	200	48	25	52	0
James River	2-JMS157.28	1/06	1	600	600	NA	NA	NA	100
Muddy Creek	2-MUY011.19	8/03 – 3/05	11	25	220	53	25	58	0
Big Lickinghole Creek	2-BLG006.41	1/06 – 3/06	3	19	410	149	19	226	33
Byrd Creek	2-BYR000.50	6/05 – 12/05	4	25	300	164	165	146	50
Byrd Creek	2-BYR003.35	1/06	1	1,800	1,800	NA	NA	NA	100
Byrd Creek	2-BYR018.04	1/06	1	3,200	3,200	NA	NA	NA	100
Byrd Creek	2-BYR021.58	1/06	1	2,300	2,300	NA	NA	NA	100
East Branch	2-EBR001.00	1/06	1	300	300	NA	NA	NA	100
Kent Branch	2-KBR001.08	1/06	1	190	190	NA	NA	NA	0
Little Byrd Creek	2-LTP002.00	1/06	1	3,000	3,000	NA	NA	NA	100
Little Byrd Creek	2-LTP004.81	1/06	1	2,200	2,200	NA	NA	NA	100
Middle Fork Kent Branch	2-MFK002.21	4/03	1	290	290	NA	NA	NA	100
Mill Creek	2-MML001.31	1/06	1	400	400	NA	NA	NA	100
Phils Creek	2-PHL001.46	1/06	1	340	340	NA	NA	NA	100
Ransome Creek	2-RSM001.88	4/05	1	10	10	NA	NA	NA	0
Venable Creek	2-VNB001.89	1/06	1	3,400	3,400	NA	NA	NA	100
Big Lickinghole Creek	2-BLG002.60	7/03 – 1/06	11	25	1,300	260	100	427	18
Big Lickinghole Creek	2-BLG008.60	1/06	1	420	420	NA	NA	NA	100
Big Lickinghole Creek	2-BLG011.41	4/05	1	40	40	NA	NA	NA	0
Big Lickinghole Creek	2-BLG006.41	1/06	1	410	410	NA	NA	NA	100
Little Lickinghole Creek	2-LIH005.28	1/06	1	770	770	NA	NA	NA	100
Tarred Rat Creek	2-TRT001.23	1/06	1	340	340	NA	NA	NA	100
White Hall Creek	2-WHC000.46	1/06	1	720	720	NS	NA	NA	100
UT to Little Lickinghole Creek	2-XVX000.62	3/04	1	10	10	NA	NA	NA	0

Table 2.2 **Summary of *E. coli* (cfu/100 ml) sampling conducted by VADEQ for period July 2003 through December 2005 (cont.).**

Stream Name	Station Id	Sampled Dates	Count	Minimum	Maximum	Mean	Median	Standard Deviation	Violation %
Beaverdam Creek	2-BDC000.79	6/05 – 1/06	5	44	250	145	150	78	20
Beaverdam Creek	2-BDC003.52	1/06	1	1	1	NA	NA	NA	0
Branch Creek	2-BNH001.76	1/06	1	25	25	NA	NA	NA	0
Courthouse Creek	2-CTS003.23	7/03 - 1/06	11	21	600	133	50	180	18
Courthouse Creek	2-CTS007.27	1/06	1	280	280	NA	NA	NA	100
Fine Creek	2-FIN000.81	7/03 – 1/06	15	10	630	102	40	159	13
James River	2-JMS140.00	1/06	1	660	660	NA	NA	NA	100

2.4.1.2 Water Quality Monitoring Conducted During TMDL Development

Ambient water quality monitoring was performed from January 2006 through April 2007. Specifically, water quality samples were taken at 25 sites throughout the James River and Tributaries – Lower Piedmont Region. Samples were analyzed for fecal coliform, *E. coli* and *enterococci* concentrations, based upon the nature of the impairment. Six of these sites were also analyzed for bacteria source (*i.e.*, human, livestock, pet, wildlife) by the Environmental Diagnostics Laboratory (EDL) at MapTech, Inc. (Figure 2. 3). Tables 2.3 and 2.4 summarize the fecal coliform and *E. coli* concentration data, respectively, at the ambient stations. BST results are presented and discussed in greater detail in Section 2.4.2.1.

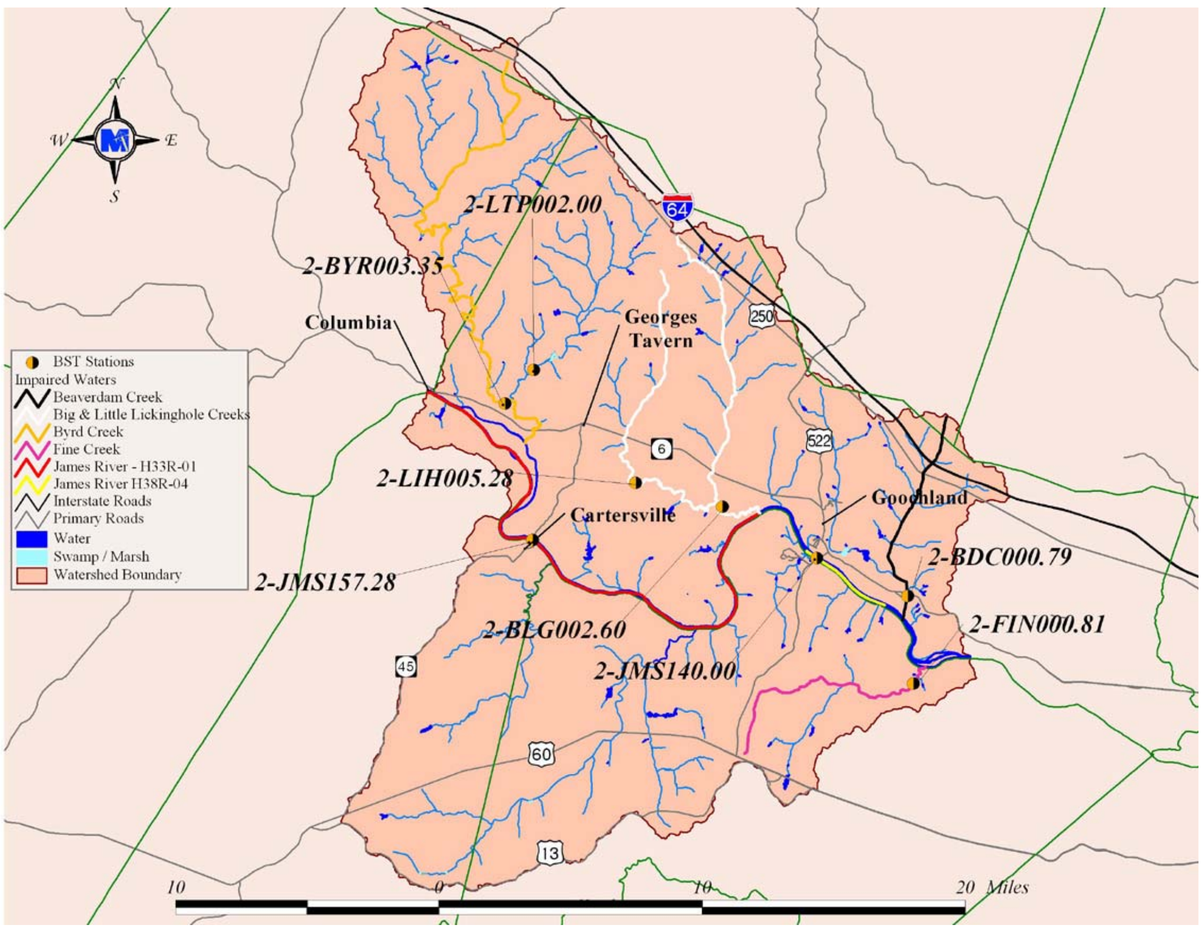

Figure 2.3 Location of BST water quality monitoring stations in the James River and Tributaries – Lower Piedmont Region.

Table 2.3 Summary of fecal coliform (cfu/100 ml) sampling conducted by VADEQ during TMDL development.

Station	Count (#)	Minimum (cfu/100ml)	Maximum (cfu/100ml)	Mean (cfu/100ml)	Median (cfu/100ml)	Standard Deviation	Violations[1] (%)
2-BNH003.00	1	380	380	NA	NA	NA	0%
2-FIN000.81	6	25	75	38	25	21	0%
2-JMS140.00	1	75	75	NA	NA	NA	0%
2-JMS154.44	1	25	25	NA	NA	NA	0%
2-JMS157.28	2	20	25	23	23	4	0%

[1]Violations based on new fecal coliform instantaneous standard (*i.e.*, 400 cfu/100ml)

Table 2.4 Summary of *E. coli* (cfu/100 ml) sampling conducted by VADEQ during TMDL development.

Station	Count (#)	Minimum (cfu/100ml)	Maximum (cfu/100ml)	Mean (cfu/100ml)	Median (cfu/100ml)	Standard Deviation	Violations[1] (%)
2-BDC000.79	18	25	750	202	99	208	28%
2-BDC003.52	12	1	2,500	287	67	703	17%
2-BLG002.60	14	30	581	118	82	141	7%
2-BLG008.60	12	10	420	69	28	116	8%
2-BLG012.33	12	3	140	55	56	36	0%
2-BLGOO6.41	12	16	610	176	75	222	25%
2-BNH001.76	11	10	75	40	42	20	8%
2-BYR000.50	6	25	100	42	25	30	0%
2-BNH003.00	1	410	410	NA	NA	NA	100%
2-BYR003.35	12	14	1,068	152	57	296	17%
2-BYR018.04	11	4	3,200	338	42	950	9%
2-BYR021.58	18	16	2,300	225	61	526	17%
2-CTS003.23	12	21	1,300	163	41	361	8%
2-CTS007.27	12	36	1,600	381	225	435	50%
2-DCR003.00	6	25	100	38	25	31	0%
2-DCR007.93	5	14	200	98	100	76	0%
2-EBR001.00	11	18	300	67	34	85	9%
2-FIN000.81	24	14	675	71	35	132	4%
2-JMS140.00	14	9	290	54	26	74	7%
2-JMS154.44	1	10	10	NA	NA	NA	0%
2-JMS157.28	18	9	594	63	22	135	6%
2-KBR001.08	12	11	190	47	25	50	0%
2-LIH005.28	17	13	770	123	37	218	18%
2-LTP002.00	11	8	3,000	353	75	882	18%
2-LTP004.81	12	11	3,000	510	81	994	33%
2-MUY001.23	5	9	100	49	21	47	0%
2-PHL001.46	12	4	480	130	55	156	25%
2-SLE002.65	6	25	180	88	63	62	0%
2-TRT001.23	11	11	340	111	48	136	27%
2-VNB001.89	12	30	3,400	423	150	944	25%
2-WHC000.46	12	13	6,600	630	27	1,891	17%
2-XYQ001.31	2	20	1,500	760	760	1,047	50%

[1]Violations based on *E. coli* instantaneous standard (*i.e.*, 235 cfu/100ml)

2.4.1.3 Bacterial Source Tracking

The data collected were analyzed for frequency of violations, patterns in fecal source identification, and seasonal impacts. Results of the analyses are presented in the following sections.

MapTech, Inc. was contracted to perform an analysis of *E. coli* concentration as well as bacterial source tracking (BST). BST is intended to aid in identifying sources (*i.e.*, human, pets, livestock, or wildlife) of fecal contamination in water bodies. Data collected provided insight into the likely sources of fecal contamination, aided in distributing fecal loads from different sources during model calibration, and will improve the chances for success in implementing solutions.

Several procedures are currently under study for use in BST. Virginia has adopted the Antibiotic Resistance Analysis (ARA) methodology implemented by MapTech's EDL. This method was selected because it has been demonstrated to be a reliable procedure for confirming the presence or absence of human, pet, livestock and wildlife sources in watersheds in Virginia. The results were reported as the percentage of isolates acquired from the sample that were identified as originating from either humans, pets, livestock, or wildlife.

The BST results of water samples collected at six ambient stations in the James River and Tributaries – Lower Piedmont Region drainage are reported in Tables 2.5 through 2.10. The *E. coli* enumerations are given to indicate the bacteria concentrations at the time of sampling. The proportions reported are formatted to indicate statistical significance (*i.e.*, **BOLD** numbers indicate a statistically significant result). The statistical significance was determined through two tests. The first was based on the sample size. A z-test was used to determine if the proportion was significantly different from zero (alpha = 0.10). Second, the rate of false positives was calculated for each source category in each library, and a proportion was not considered significantly different from zero unless it was greater than the false-positive rate plus three standard deviations. Table 2.11 summarizes the average proportions of bacteria originating from the four source categories measured at each station. The weighted average considers the concentration of *E. coli* measured on day of sampling and the number of bacterial isolates analyzed in the BST analysis. The weighted average also considers flow on day of sampling when such flow measurements exist (Fine Creek and the two James River stations).

Table 2.5 Summary of bacterial source tracking results from water samples collected in the Beaverdam Creek impairment.

Station ID	Date of Sample	No. of Isolates	E. Coli cfu/100ml	Percent Isolates Classified as: Wildlife	Human	Livestock	Pet
2BDC000.79	1/10/2006	24	74	12%	**33%**	**33%**	**22%**
	2/1/2006	24	96	**67%**	4%	8%	**21%**
	3/1/2006	24	92	**79%**	0%	4%	17%
	4/10/2006	24	86	**92%**	0%	0%	8%
	5/1/2006	23	160	**56%**	0%	9%	**35%**
	6/5/2006	24	800	**92%**	4%	0%	4%
	7/11/2006	22	310	**90%**	0%	5%	5%
	8/8/2006	17	220	**46%**	24%	12%	18%
	9/5/2006	24	450	**80%**	4%	12%	4%
	10/2/2006	24	270	4%	8%	4%	**84%**
	11/7/2006	5	20	40%	20%	20%	20%
	12/12/2006	19	78	0%	**42%**	5%	**53%**

BOLD type indicates a statistically significant value.

Table 2.6 Summary of bacterial source tracking results from water samples collected in the Big Lickinghole Creek impairment.

Station ID	Date of Sample	No. of Isolates	E. Coli cfu/100ml	Percent Isolates Classified as: Wildlife	Human	Livestock	Pet
2BLG002.60	1/3/2006	24	262	**42%**	12%	**21%**	**25%**
	2/1/2006	24	44	**100%**	0%	0%	0%
	3/1/2006	10	70	10%	0%	**60%**	**30%**
	4/10/2006	24	53	**84%**	0%	12%	4%
	5/1/2006	13	90	0%	**46%**	**31%**	**23%**
	6/5/2006	24	68	**92%**	8%	0%	0%
	7/26/2006	24	98	8%	**71%**	**17%**	4%
	8/14/2006	23	100	**65%**	4%	9%	**22%**
	9/18/2006	24	98	**50%**	0%	12%	**38%**
	10/2/2006	24	90	4%	0%	0%	**96%**
	11/6/2006	17	42	6%	**47%**	**41%**	6%
	12/12/2006	23	150	0%	**30%**	**17%**	**53%**

BOLD type indicates a statistically significant value.

Table 2.7 Summary of bacterial source tracking results from water samples collected in the Byrd Creek impairment.

Station ID	Date of Sample	No. of Isolates	E. Coli cfu/100ml	Percent Isolates Classified as: Wildlife	Human	Livestock	Pet
2BYR003.35	01/03/06	24	336	4%	0%	**79%**	**17%**
	02/01/06	23	50	**82%**	9%	0%	9%
	03/01/06	6	18	100%	0%	0%	0%
	04/10/06	24	70	**88%**	4%	0%	8%
	05/01/06	3	84	67%	33%	0%	0%
	06/05/06	24	106	**80%**	4%	8%	8%
	07/25/06	22	62	**54%**	5%	**32%**	9%
	08/14/06	19	88	**42%**	0%	11%	**47%**
	09/18/06	21	250	**47%**	**29%**	10%	**14%**
	10/02/06	24	64	**66%**	**17%**	**17%**	0%
	11/06/06	8	14	50%	12%	38%	0%
	12/12/06	17	26	6%	6%	0%	**88%**

BOLD type indicates a statistically significant value.

Table 2.8 Summary of bacterial source tracking results from water samples collected in the Fine Creek impairment.

Station ID	Date of Sample	No. of Isolates	E. Coli cfu/100ml	Percent Isolates Classified as: Wildlife	Human	Livestock	Pet
2FIN000.81	01/10/06	14	30	**21%**	**58%**	14%	7%
	02/01/06	10	20	**100%**	0%	0%	0%
	03/01/06	8	22	38%	12%	50%	0%
	04/10/06	8	20	100%	0%	0%	0%
	05/03/06	23	92	0%	0%	**43%**	**57%**
	06/05/06	22	66	**85%**	5%	5%	5%
	07/11/06	24	130	**80%**	4%	4%	**12%**
	08/14/06	12	34	**25%**	8%	8%	**59%**
	09/05/06	24	720	**54%**	0%	**46%**	0%
	10/02/06	24	70	8%	8%	0%	**84%**
	11/07/06	16	64	**76%**	12%	6%	6%
	12/12/06	19	28	0%	5%	0%	**95%**

BOLD type indicates a statistically significant value.

Table 2.9 Summary of bacterial source tracking results from water samples collected in the James River impairment.

Station ID	Date of Sample	No. of Isolates	E. Coli cfu/100ml	Percent Isolates Classified as: Wildlife	Human	Livestock	Pet
2JMS140.00	01/03/06	24	290	**46%**	4%	**25%**	**25%**
	02/01/06	7	14	86%	0%	0%	14%
	03/01/06	14	44	**28%**	0%	**36%**	**36%**
	04/10/06	6	8	100%	0%	0%	0%
	05/01/06	2	18	0%	50%	50%	0%
	06/05/06	12	50	**58%**	8%	17%	17%
	07/26/06	20	136	**55%**	10%	**30%**	5%
	08/14/06	19	72	**100%**	0%	0%	0%
	09/18/06	14	26	**86%**	0%	0%	14%
	10/02/06	9	24	0%	11%	0%	**89%**
	11/06/06	3	16	34%	33%	0%	33%
	12/12/06	14	26	7%	14%	14%	**65%**

BOLD type indicates a statistically significant value.

Table 2.10 Summary of bacterial source tracking results from water samples collected in the James River impairment.

Station ID	Date of Sample	No. of Isolates	E. Coli cfu/100ml	Percent Isolates Classified as: Wildlife	Human	Livestock	Pet
2JMS157.28	01/03/06	24	588	**29%**	4%	**46%**	**21%**
	02/13/06	11	20	**55%**	0%	**36%**	9%
	03/01/06	2	4	50%	0%	50%	0%
	04/10/06	8	12	50%	0%	50%	0%
	05/01/06	7	16	14%	57%	29%	0%
	06/05/06	16	34	**82%**	6%	12%	0%
	07/26/06	9	30	**89%**	0%	0%	11%
	08/14/06	6	16	33%	17%	17%	33%
	09/18/06	24	80	**80%**	4%	8%	8%
	10/02/06	14	26	0%	0%	0%	**100%**
	11/06/06	6	18	50%	33%	0%	17%
	12/12/06	18	34	6%	6%	0%	**88%**

BOLD type indicates a statistically significant value.

Table 2.11 Average proportions of fecal bacteria originating from wildlife, human, livestock, and pet sources.

Station ID	Weighted Averages: Wildlife	Human	Livestock	Pet
2-BYR003.35	32	14	36	18
2-BLG002.60	38	18	17	27
2-FIN000.81	34	4	24	38
2-BDC000.79	66	7	9	18
2-JMS140.00	37	5	37	21
2-JMS157.28	26	8	47	19

2.4.2 Trend and Seasonal Analyses

In order to improve TMDL allocation scenarios and, therefore, the success of implementation strategies, trend and seasonal analyses were performed on precipitation, discharge, and fecal coliform concentrations. A Seasonal Kendall Test was used to examine long-term trends. The Seasonal Kendall Test ignores seasonal cycles when looking for long-term trends. This improves the chances of finding existing trends in data that are likely to have seasonal patterns. Additionally, trends for specific seasons can be analyzed. For instance, the Seasonal Kendall Test can identify the trend (over many years) in discharge levels during a particular season or month.

A seasonal analysis of precipitation, discharge, and fecal coliform concentration data were conducted using the Mood Median Test. This test was used to compare median values of precipitation, discharge, and fecal coliform concentrations in each month.

2.4.2.1 Precipitation

Total monthly precipitation measured at stations Crozier (442142), Powhatan (446906), and Cumberland (442160) was analyzed and no overall, long-term trends were found.

2.4.2.2 Discharge

Total monthly flow measured at USGS Gaging Station #02037500 on the James River near Richmond, Virginia from October 1934 to September 2004 was analyzed and an overall, long-term decrease in flow was found.

Differences in mean monthly flow rates at Station #02037500 were observed. In general, flow rate was statistically similar for the months of January through April. Flow rate was also statistically similar for the months of September through November. The first group of months (January through April) experienced higher flow rates than the second group (September through November). Generally, flow decreased from May to August.

2.4.2.3 Fecal Coliform Concentrations

Water quality monitoring data collected by VADEQ were described in section 2.4.1.1. The trend analysis was conducted on data, if sufficient, collected at stations used in TMDL assessment. As a result, the trend and seasonality analysis was conducted on VADEQ stations 2-JMS157.28, 2-FIN000.81, 2-DCR003.00, 2-BYR003.35, 2-BLG002.60, 2-BDC000.79. None of the stations showed overall trends or seasonality.

3. SOURCE ASSESSMENT

The TMDL development described in this report includes examination of all potential sources of fecal coliform in the James River and Tributaries – Lower Piedmont Region. The source assessment was used as the basis of model development and ultimate analysis of TMDL allocation options. In evaluation of the sources, loads were characterized by the best available information, landowner input, literature values, and local management agencies. Section 3.1 documents the available information and interpretation for the analysis. The source assessment chapter includes point source and nonpoint source sections. The representation of those sources in the model is discussed in Section 4.

3.1 Watershed Characterization

The National Land Cover Database 2001 (NLCD) produced cooperatively between the U.S. Geological Survey (USGS) and U.S. Environmental Protection Agency (EPA) was utilized for this study. The collaborative effort to produce this dataset is part of a Multi-Resolution Land Characteristics (MRLC) Consortium project led by four U.S. government agencies: EPA, USGS, the Department of the Interior National Biological Service (NBS), and the National Oceanic and Atmospheric Administration (NOAA). Using 30-meter resolution Landsat 7 Thematic Mapper (TM) satellite images taken between 1999 and 2001, digital land use coverage was developed identifying up to 29 possible land use types. Classification, interpretation, and verification of the land cover dataset involved several data sources when available including: aerial photography; soils data; population and housing density data; state or regional land cover data sets; USGS land use and land cover (LUDA) data; 3-arc second Digital Terrain Elevation Data (DTED) and derived slope, aspect and shaded relief; and National Wetlands Inventory (NWI) data. Approximate acreages and land use proportions for each impaired segment are given in Table 3.1 and shown in Figure 3.1.

Table 3.1 Contributing land use area for impaired segments in the James River and Tributaries – Lower Piedmont Region.

Impaired Segment	Land use								
	Water (acres)	Low Density Residential (acres)	Commercial (acres)	Barren (acres)	Forest (acres)	Pasture (acres)	Cropland (acres)	Wetlands (acres)	Livestock Access* (acres)
Byrd Creek, H34R-01	646.9	1852.2	0.0	135.4	55,601.5	11,642.0	190.8	1,964.1	170.3
Big & Little Lickinghole Creeks, H37R-01	457.1	1225.6	0.0	116.6	34,637.0	6,580.7	395.1	1,865.4	108.1
Fine Creek, H38R-01	330.4	635.2	1.9	140.6	10,067.4	2,898.0	166.8	694.2	32.8
Beaverdam Creek, H38R-03	418.4	1340.9	1.3	84.1	16,942.2	5,493.7	495.4	920.7	104.1
James River, H33R-01 (upper)	3886.6	5625.2	0.0	689.2	174,657.3	37,025.3	1,677.2	7,329.9	518.4
James River, H38R-04 (lower)	6049.0	8522.0	6.1	929.7	217,160.3	50,787.7	2,991.7	9,561.0	762.3

*"Livestock Access" are areas of pasture within close proximity to accessible streams

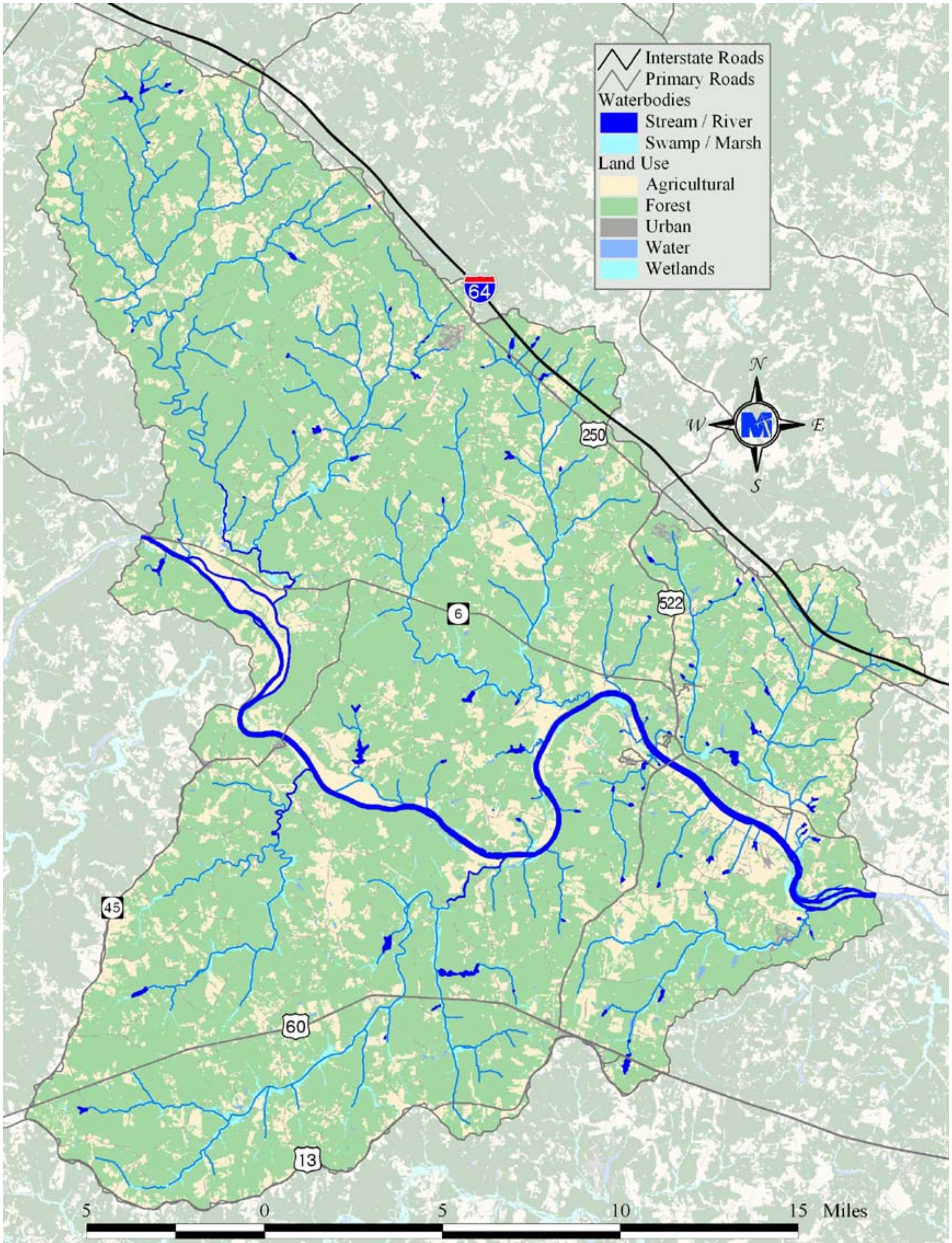

Figure 3.1 Land uses in the James River and Tributaries – Lower Piedmont Region watershed.

As for climate of the study area, for the period from 1950 to 2005, the area around Powhatan, Virginia (station # 446906) received an average annual precipitation of approximately 42.04 inches, with 52% of the precipitation occurring during the May through October growing season (SERCC, 2006). Average annual snowfall is 9.2 inches, with the highest snowfall occurring during January (SERCC, 2006). Average annual daily temperature is 56.5 ºF. The highest average daily temperature of 89.0 ºF occurs in July, while the lowest average daily temperature of 24.4 ºF occurs in January (SERCC, 2006).

3.2 Assessment of Point Sources

Eighteen point sources are permitted in the James River and Tributaries – Lower Piedmont Region through the Virginia Pollutant Discharge Elimination System (VPDES) (Table 3.2). Eight of those permits are Single Family Home (SFH) permits. Figure 3.2 shows the non SFH permitted locations. Permitted point discharges that may contain pathogens associated with fecal matter are required to maintain a fecal coliform concentration below 200 cfu/100 ml. Currently, these permitted discharges are expected not to exceed the 126 cfu/100mL *E. coli* standard. One method for achieving this goal is chlorination. Chlorine is added to the discharge stream at levels intended to kill off any pathogens. The monitoring method for ensuring the goal is to measure the concentration of total residual chlorine (TRC) in the effluent. If the concentration is high enough, pathogen concentrations (including fecal coliform concentrations) are considered reduced to acceptable levels. Typically, if minimum TRC levels are met, bacteria concentrations are reduced to levels well below the standard.

Table 3.3 summarizes data from VPDES Confined Animal Feeding Operations (CAFO) and from Virginia Pollution Abatement (VPA) facilities along with the streams that receive potential runoff from these facilities. Figure 3.2 shows the VPA and CAFO locations. These permitted sources do not have direct discharges to waterways but runoff from the area could contain fecal coliform and *E. coli* bacteria.

Table 3.2 Summary of VPDES permitted point sources in the James River and Tributaries – Lower Piedmont Region.

Facility Name	Permit No	Stream	Design Flow (MGD)	Permitted For Fecal Control
Elk Hill Farm WWTP	VA0062731	Little River/UT	0.0125	YES
Covenance Research Products Inc.	VA0088382	Maxey Mill Creek	0.020	YES
DJJ Beaumont Juvenile Correction Center	VA0020656	Mohawk Creek	0.090	YES
James River Correction Center	VA0020681	James River	0.216	YES
James River Correction Center	VA0006149	Beaverdam Creek	0.060	YES
DOC Powhatan Correctional Center	VA0020699	UT to James River	0.465	YES
Virginia Correctional Center for Women	VA0020702	James River	0.196	YES
VDOT Interstate 64 Goochland Rest Area	VA0023108	Horsepen Creek	0.020	YES
Huguenot Academy Incorporated	VA0063037	UT to Branch Creek	0.004	YES
Powhatan Courthouse WTP 2	VA0084565	UT of Branch Creek	--	No
Domestic Sewage Discharge	VAG404239	UT Mill Creek	0.001	YES
Domestic Sewage Discharge	VAG404240	UT Mill Creek	0.001	YES
Domestic Sewage Discharge	VAG406343	Venable Creek UT	0.001	YES
Domestic Sewage Discharge	VAG406344	Venable Creek UT	0.001	YES
Domestic Sewage Discharge	VAG406345	Venable UT	0.001	YES
Domestic Sewage Discharge	VAG406346	Venable Creek UT	0.001	YES
Domestic Sewage Discharge	VAG406347	Venable Creek UT	0.001	YES
Domestic Sewage Discharge	VAG404226	UT Maple Swamp Creek	0.001	YES

Table 3.3 Summary of CAFO permits in the James River and Tributaries – Lower Piedmont Region.

Facility Name	Permit No	Adjacent Receiving Stream	Type
Oakview Farm Inc.	VPG140045	Solomon’s Creek/UT	Dairy
Oakview Farm Inc.	VPG100061	Solomon’s Creek/UT	Poultry
Hamton Farm	VPG270089	James River	Poultry

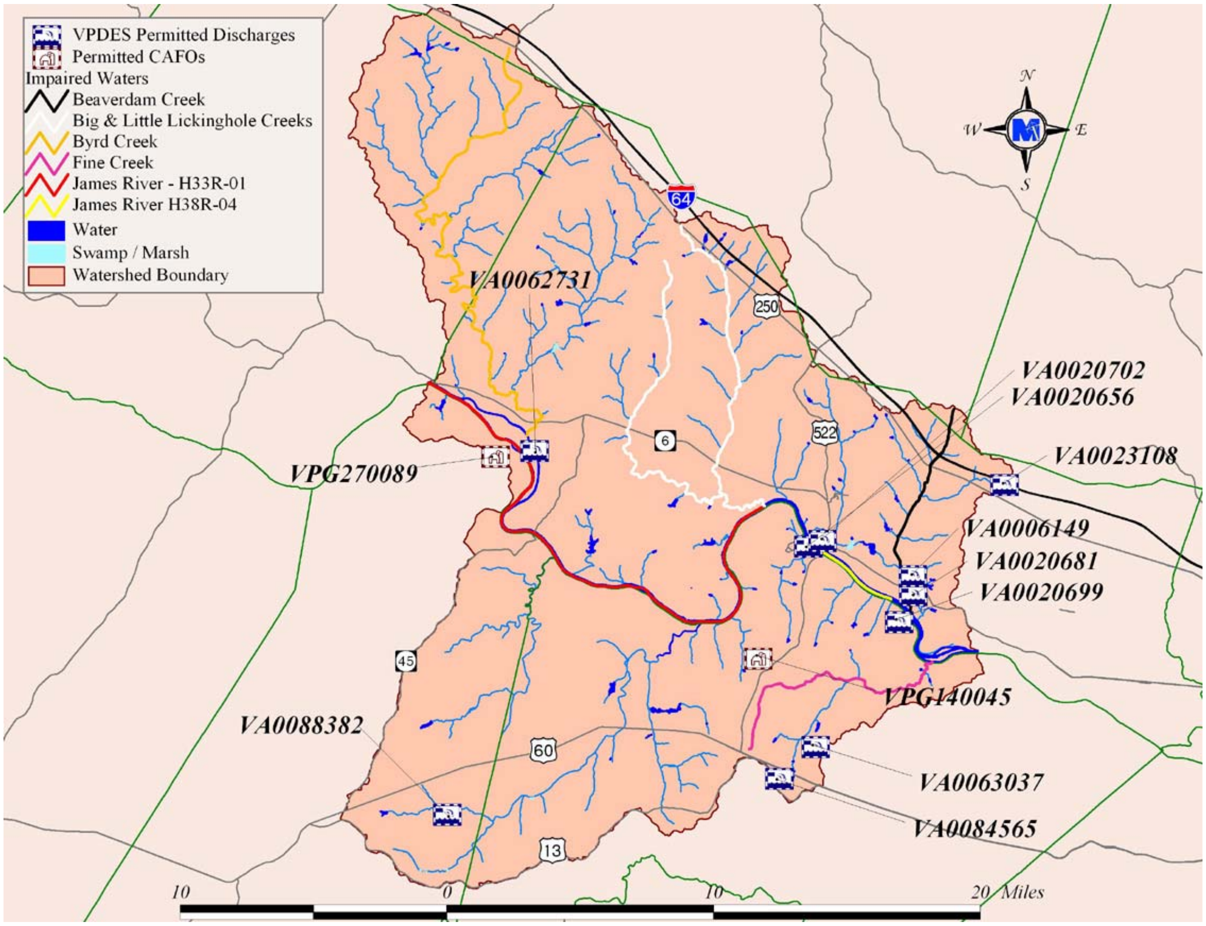

Figure 3.2 Location of VPDES permitted point sources and CAFOs in the James River and Tributaries – Lower Piedmont Region.

3.3 Assessment of Nonpoint Sources

In the James River and Tributaries – Lower Piedmont Region, both urban and rural nonpoint sources of fecal coliform bacteria were considered. Sources include residential sewage treatment systems, land application of waste (livestock and biosolids), livestock, wildlife, and pets. Sources were identified and enumerated. MapTech previously collected samples of fecal coliform sources (*i.e.*, wildlife, livestock, pets, and human waste) and enumerated the density of fecal coliform bacteria to support the modeling process and to expand the database of known fecal coliform sources for purposes of bacterial source tracking (Section 2.4.2.1). Where appropriate, spatial distribution of sources was also determined.

3.3.1 Private Residential Sewage Treatment

In the U.S. Census questionnaires, housing occupants were asked which type of sewage disposal existed. Houses can be connected to a public sanitary sewer, a septic tank, or a cesspool, or the sewage is disposed of in some other way. The Census category “Other Means” includes the houses that dispose of sewage other than by public sanitary sewer or a private septic system. The houses included in this category are assumed to be disposing of sewage via a pit-privy or through the use of a straight pipe (direct stream outfall). Population, housing units, and type of sewage treatment from U.S. Census Bureau were summarized using GIS (Table 3.4). Census date from 1990 and 2000 were used to project forward to the year 2006.

Sanitary sewers are piping systems designed to collect wastewater from individual homes and businesses and carry it to a wastewater treatment plant. Sewer systems are designed to carry a specific "peak flow" volume of wastewater to the treatment plant. Within this design parameter, sanitary collection systems are not expected to overflow, surcharge or otherwise release sewage before their waste load is successfully delivered to the wastewater treatment plant.

When the flow of wastewater exceeds the design capacity, the collection system will "back up" and sewage discharges through the nearest escape location. These discharges into the environment are called overflows. Wastewater can also enter the environment through exfiltration caused by line cracks, joint gaps, or breaks in the piping system.

Typical private residential sewage treatment systems (septic systems) consist of a septic tank, distribution box, and a drainage field. Waste from the household flows first to the septic tank, where solids settle out and are periodically removed by a septic tank pump-out. The liquid portion of the waste (effluent) flows to the distribution box, where it is distributed among several buried, perforated pipes that comprise the drainage field. Once in the soil, the effluent flows downward to groundwater, laterally to surface water, and/or upward to the soil surface. Removal of fecal coliform is accomplished primarily by die-off during the time between introduction to the septic system and eventual introduction to naturally occurring waters. Properly designed, installed, and functioning septic systems contribute virtually no fecal coliform to surface waters.

A septic failure occurs when a drain field has inadequate drainage or a "break", such that effluent flows directly to the soil surface, bypassing travel through the soil profile. In this situation, the effluent is either available to be washed into waterways during runoff events or is directly deposited in-stream due to proximity. A survey of septic pump-out contractors previously performed by MapTech showed that failures were more likely to occur in the winter-spring months than in the summer-fall months, and that a higher percentage of system failures were reported because of a back-up to the household than because of a failure noticed in the yard.

MapTech previously sampled waste from septic tank pump-outs and found an average fecal coliform density of 1,040,000 cfu/100 ml (MapTech, 2001). An average fecal coliform density for human waste of 13,000,000 cfu/g and a total waste load of 75 gal/day/person was reported by Geldreich (1978).

Table 3.4 Human population, housing units, houses on sanitary sewer, septic systems, and other sewage disposal systems for 2006 in areas contributing to impaired segments in the James River and Tributaries – Lower Piedmont Region.

Impaired Segment	Population	Housing Units	Sanitary Sewer	Septic Systems	Other *
Byrd Creek	3,809	1,561	32	1,493	36
Big Lickinghole Creek/ Little Lickinghole Creek	3,718	1,422	21	1,385	16
Fine Creek	2,170	835	15	813	7
Beaverdam Creek	4,069	1,551	0	1,523	28
James River (H33R-01)	14,543	5,540	40	5,375	125
James River (H38R-04)	26,483	8,682	54	8,480	148

* Houses with sewage disposal systems other than sanitary sewer and septic systems.

3.3.2 Biosolids

During the water quality modeling period between 1997 and 2001, biosolids were applied to several subwatersheds within the James River and Tributaries – Lower Piedmont Region. The total amount of biosolids applied was 6,759 dry tons (Table 3.5). The application of biosolids to agricultural lands is strictly regulated in Virginia (VDH, 1997). The task of regulating biosolids application in Virginia was transferred in 2007 from the Department of Health to the Department of Environmental Quality. Biosolids are required to be spread according to sound agronomic requirements with consideration for topography and hydrology. Class B biosolids may not have a fecal coliform density greater than 1,995,262 cfu/g (total solids). Application rates must be limited to a maximum of 15 dry tons/acre per three-year period.

Table 3.5 Application of dry biosolids within the James River and Tributaries – Lower Piedmont Region during water quality calibration/validation.

Impairment	Dry Tons Applied In				
	1997	1998	1999	2000	2001
Byrd Creek	--	--	--	--	--
Big & Little Lickinghole Creeks	--	--	--	--	--
Beaverdam Creek	--	--	--	--	--
Fine Creek	--	--	--	--	--
James River (H33R-01)	988	876	1,681	1,158	1,530
James River (H38R-04)	988	876	1,681	1,158	2,056

3.3.3 Pets

Among pets, cats and dogs are the predominant contributors of fecal coliform in the James River and Tributaries – Lower Piedmont Region and were the only pets considered in this analysis. Cat and dog populations by household were derived from American Veterinary Medical Association Center for Information Management 1997 demographics. Dog waste load was reported by Weiskel et al. (1996), while cat waste load was measured during the Blackwater River TMDL study conducted by Maptech. Fecal coliform density for dogs and cats was previously measured from samples collected throughout Virginia by MapTech. A summary of the data collected is given in Table 3.6. Table 3.7 lists the domestic animal populations for impairments in the James River and Tributaries – Lower Piedmont Region.

Table 3.6 Domestic animal population density, waste load, and fecal coliform density.

Type	Population Density (an/house)	Waste load (g/an-day)	FC Density (cfu/g)
Dog	0.534	450	480,000
Cat	0.598	19.4	9

Table 3.7 Estimated domestic animal populations in areas contributing to impaired segments in the James River and Tributaries – Lower Piedmont Region.

Impaired Segment	Dogs	Cats
Byrd Creek	830	933
Little Lickinghole Creek Big Lickinghole Creek	759	850
Fine Creek	415	499
Beaverdam Creek	817	928
James River, H38R-04	4,597	5,192
James River, H33R-03	2,949	3,313

3.3.4 Livestock

Several types of livestock exist within the watersheds of the impaired streams of the James River and Tributaries – Lower Piedmont Region including poultry, beef cattle, horses, sheep, and dairy. However, all types of livestock identified were considered in modeling the watershed. Table 3.8 gives a summary of livestock populations in the James River and Tributaries – Lower Piedmont Region during the period for source assessment, organized by impairment. Animal populations were based on communication with Virginia Cooperative Extension Service (VCE), Virginia Department of Conservation and Recreation (VADCR), Natural Resources Conservation Service (NRCS), Monacan Soil and Water Conservation District (MSWCD), Peter Francisco Soil and Water Conservation District (PFSWCD), Thomas Jefferson Soil and Water Conservation District (TJSWCD), Farm Services Agency, local extension agents, watershed visits, and verbal communication with farmers. Values of fecal coliform density of livestock sources were based on sampling previously performed by MapTech (MapTech, 1999a). Reported manure production rates for livestock were taken from American Society of Agricultural Engineers (1998). A summary of fecal coliform density values and manure production rates is presented in Table 3.9.

Table 3.8 Livestock populations in areas contributing to impaired segments in the James River and Tributaries – Lower Piedmont Region.

Impaired Segment	Beef	Beef (calf)	Dairy (milker)	Dairy (dry)	Dairy (calf)	Hog	Horse	Sheep	Poultry
Byrd Creek	1,300	1,000	272	83	83	15	530	44	0
Little Lickinghole Creek/ Big Lickinghole Creek	500	350	0	0	0	0	750	22	82,100
Fine Creek	300	350	0	0	0	0	350	12	0
Beaverdam Creek	675	525	150	46	46	19	474	31	0
James River, H33R-01	3,118	2,572	822	250	250	40	1,706	109	158,900
James River, H38R-04	4,225	3,375	942	286	286	70	2,823	157	260,900

Table 3.9 Average fecal coliform densities and waste loads associated with livestock.

Type	Waste Load (lb/d/an)	Fecal Coliform Density (cfu/g)
Dairy (1,400 lb)	120.4	271,000
Dairy calf (350 lb)	29.0	271,329
Beef (800 lb)	46.4	101,000
Beef calf (350 lb)	21.0	101,000
Horse (1,000 lb)	51.0	94,000
Swine (135 lb)	11.3	400,000
Swine Lagoon	N/A	95,300[1]
Sheep (60 lb)	2.4	43,000
Goat (140 lb)	5.7	15,000
Dairy Separator	N/A	32,000[1]
Dairy Storage Pit	N/A	44,600[1]
Poultry		
Broiler	0.17	586,000
Layer	0.26	586,000

[1]units are cfu/100ml

Fecal coliform produced by livestock can enter surface waters through four pathways. First, waste produced by animals in confinement is typically collected, stored, and applied to the landscape (*e.g.,* pasture and cropland), where it is available for wash-off during a runoff-producing rainfall event. Table 3.10 shows the average percentage of collected livestock waste that is applied throughout the year. Second, grazing livestock deposit manure directly on the land where it is available for wash-off during a runoff-producing rainfall event. Third, livestock with access to streams occasionally deposit manure directly in streams. Fourth, some animal confinement facilities have drainage systems that divert wash-water and waste directly to drainage ways or streams.

Table 3.10 Average percentage of collected livestock waste applied throughout year.

Month	**Applied % of Total**			**Land use**
	Dairy	***Beef***	***Poultry***	
January	2.00	4.00	0.00	Cropland
February	2.00	4.00	0.00	Cropland
March	20.00	12.00	20.00	Cropland
April	20.00	12.00	20.00	Cropland
May	5.00	12.00	5.00	Cropland
June	2.00	8.00	5.00	Pasture
July	2.00	8.00	5.00	Pasture
August	2.00	8.00	5.00	Pasture
September	21.00	12.00	20.00	Cropland
October	20.00	12.00	15.00	Cropland
November	2.00	4.00	5.00	Cropland
December	2.00	4.00	0.00	Cropland

Some livestock were expected to deposit a portion of waste on land areas. The percentage of time spent on pasture for dairy and beef cattle was reported by the NRCS, VADCR, and VCE (Tables 3.11 and 3.12) and local stakeholders. Horses and sheep were assumed to be in pasture 100% of the time.

Based on discussions with local stakeholders, VCE, and NRCS, it was concluded that beef cattle were expected to make a significant contribution through direct deposition with access to flowing water. In areas with stream fencing BMPs in place, or areas with large amounts of standing or slowly moving water (*i.e.*, swamps), it was concluded that direct deposition was minimal to non-existent. For areas where direct deposition by cattle is assumed, the average amount of time spent by dairy and beef cattle in stream access areas (*i.e.*, within 50 feet of the stream) for each month is given in Tables 3.11 through Table 3.12.

Table 3.11 Average time dry cows and replacement heifers spend in different areas per day.

Month	Pasture (hr)	Stream Access (hr)	Loafing Lot (hr)
January	23.3	0.7	0
February	23.3	0.7	0
March	22.6	1.4	0
April	21.8	2.2	0
May	21.8	2.2	0
June	21.1	2.9	0
July	21.1	2.9	0
August	21.1	2.9	0
September	21.8	2.2	0
October	22.6	1.4	0
November	22.6	1.4	0
December	23.3	0.7	0

Table 3.12 Average time beef cows not confined in feedlots spend in pasture and stream access areas per day.

Month	Pasture (hr)	Stream Access (hr)
January	23.3	0.7
February	23.3	0.7
March	23.0	1.0
April	22.6	1.4
May	22.6	1.4
June	22.3	1.7
July	22.3	1.7
August	22.3	1.7
September	22.6	1.4
October	23.0	1.0
November	23.0	1.0
December	23.3	0.7

3.3.5 Wildlife

The predominant wildlife species in the James River and Tributaries – Lower Piedmont Region were determined through consultation with wildlife biologists from the Virginia Department of Game and Inland Fisheries (VDGIF), United States Fish and Wildlife Service (FWS), citizens from the watershed, source sampling, and site visits. A great amount of feedback on initial estimates was organized by the Monacan Soil and Water Conservation District (MSWCD) and wildlife populations were modified to reflect this feedback. Population densities were calculated from data provided by VDGIF and FWS, and are listed in Table 3.13 (Bidrowski, 2004; Farrar, 2003; Fies, 2004; Knox, 2004; Norman, 2004; Raftovich, 2004; Rose and Cranford, 1987). The numbers of animals estimated to be in the James River and Tributaries – Lower Piedmont Region are reported in Table 3.14. Habitat and seasonal food preferences were determined based on information obtained from The Fire Effects Information System (1999) and VDGIF (Costanzo, 2003; Norman, 2003; Rose and Cranford, 1987; and VDGIF, 1999). Waste loads were comprised from literature values and discussion with VDGIF personnel (ASAE, 1998; Bidrowski, 2003; Costanzo, 2003; Weiskel et al., 1996, and Yagow, 1999b). Table 3.15 summarizes the habitat and fecal production information that was obtained. Where available, fecal coliform densities were based on sampling of wildlife scat performed by MapTech. The only value that was not obtained from MapTech sampling in the watershed was for beaver. The fecal coliform density of beaver waste was taken from sampling done for the Mountain Run TMDL development (Yagow, 1999a). Percentage of time spent in stream access areas and percentage of waste directly deposited to streams was based on habitat information and location of feces during source sampling. Fecal coliform densities and estimated percentages of time spent in stream access areas (*i.e.*, within 100 feet of stream) are reported in Table 3.16.

Table 3.13 Wildlife population density in the James River and Tributaries – Lower Piedmont Region.

Deer (an/ac of habitat)	Turkey (an/ac of habitat)	Goose (an/ac of habitat)	Duck (an/ac of habitat)	Muskrat (an/ac of habitat)	Raccoon (an/ac of habitat)	Beaver (an/mi of stream)	Beaver (an/mi along lakes, marshes, rivers)
0.0339	0.0069	0.0222	0.0222	0.5981	0.0173	3.0	2.4

Table 3.14 Wildlife populations in the James River and Tributaries – Lower Piedmont Region.

Impairment	Deer	Turkey	Goose	Duck	Muskrat	Raccoon	Beaver
Byrd Creek	2,469	497	466	466	3,138	636	425
Little Lickinghole Creek & Big Lickinghole Creek	1,933	314	242	242	1,628	751	186
Fine Creek	1,996	95	80	80	539	254	61
Beaverdam Creek	1,571	159	182	182	1,228	487	134
James River, H33R-01	6,293	1,260	951	951	6,407	2,346	942
James River, H38R-04	9,029	1,720	1,354	1,354	9,122	3,535	1,403

Table 3.15 Wildlife fecal production rates and habitat.

Animal	Waste Load (g/an-day)	Habitat
Raccoon	450	Primary = region within 600 ft of perennial streams Secondary = region between 601 and 7,920 ft from perennial streams Infrequent/Seldom = rest of watershed area including waterbodies (lakes, ponds)
Muskrat	100	Primary = waterbodies, and land area within 66 ft from the edge of perennial streams, and waterbodies Secondary = region between 67 and 308 ft from perennial streams, and waterbodies Infrequent/Seldom = rest of the watershed area
Beaver[1]	200	Primary = Perennial streams. Generally flat slope regions (slow moving water), food sources nearby (corn, forest, younger trees) Infrequent/Seldom = rest of the watershed area
Deer	772	Primary = forested, harvested forest land, grazed woodland, urban grassland, cropland, pasture, wetlands, transitional land Secondary = low density residential, medium density residential Infrequent/Seldom = remaining land use areas
Turkey[2]	320	Primary = forested, harvested forest land, grazed woodland, wetlands, transitional land Secondary = cropland, pasture Infrequent/Seldom = remaining land use areas
Goose[3]	225	Primary = waterbodies, and land area within 66 ft from the edge of perennial streams, and waterbodies Secondary = region between 67 and 308 ft from perennial streams, and waterbodies Infrequent/Seldom = rest of the watershed area
Duck	150	Primary = waterbodies, and land area within 66 ft from the edge of perennial streams, and waterbodies Secondary = region between 67 and 308 ft from perennial streams, and waterbodies Infrequent/Seldom = rest of the watershed area

[1]Beaver waste load was calculated as twice that of muskrat, based on field observations.
[2]Waste load for domestic turkey (ASAE, 1998).
[3]Goose waste load was calculated as 50% greater than that of duck, based on field observations and conversation with Gary Costanzo (Costanzo, 2003).

Table 3.16 Average fecal coliform densities and percentage of time spent in stream access areas for wildlife.

Animal Type	Fecal Coliform Density (cfu/g)	Portion of Day in Stream Access Areas (%)
Raccoon	2,100,000	5
Muskrat	1,900,000	90
Beaver	1,000	100
Deer	380,000	5
Turkey	1,332	5
Goose	250,000	50
Duck	3,500	75

4. MODELING PROCEDURE: LINKING THE SOURCES TO THE ENDPOINT

Establishing the relationship between in-stream water quality and the source loadings is a critical component of TMDL development. It allows for the evaluation of management options that will achieve the desired water quality endpoint. In the development of TMDLs in the James River – Lower Piedmont Region, the relationship was defined through computer modeling based on data collected throughout the watersheds. Monitored flow and water quality data were then used to verify that the relationships developed through modeling were accurate. There are five basic steps in the development and use of a water quality model: model selection, source assessment, selection of a representative modeling period, model calibration, model validation, and model simulation.

Model selection involves identifying an approved model that is capable of simulating the pollutants of interest with the available data. Source assessment involves identifying and quantifying the potential sources of pollutants in the watershed. Selection of a representative period involves the identification of a time period that accounts for critical conditions associated with all potential sources within the watershed. Calibration is the process of comparing modeled data to observed data and making appropriate adjustments to model parameters to minimize the error between observed and simulated events. Validation is the process of comparing modeled data to observed data during a period other than that used for calibration, with the intent of assessing the capability of the model in hydrologic conditions other than those used during calibration. During validation, no adjustments are made to model parameters. Once a suitable model is constructed, the model is then used to predict the effects of current loadings and potential management practices on water quality. In this section, the selection of modeling tools, source assessment, selection of a representative period, calibration/validation, and model application are discussed.

4.1 Modeling Framework Selection

The USGS Hydrologic Simulation Program - Fortran (HSPF) water quality model was selected as the modeling framework to simulate existing conditions and to perform TMDL allocations. The HSPF model is a continuous simulation model that can account for NPS pollutants in runoff, as well as pollutants entering the flow channel from point sources. In establishing the existing and allocation conditions, seasonal variations in hydrology, climatic conditions, and watershed activities were explicitly accounted for in the model. The use of HSPF allowed consideration of seasonal aspects of precipitation patterns within the watershed.

The HSPF model simulates a watershed by dividing it up into a network of stream segments (referred to in the model as RCHRES), impervious land areas (IMPLND) and pervious land areas (PERLND). Each subwatershed contains a single RCHRES, modeled as an open channel, and numerous PERLNDs and IMPLNDs, representing the various land uses in that subwatershed. Water and pollutants from the land segments in a given subwatershed flow into the RCHRES in that subwatershed. Point discharges and withdrawals of water and pollutants are simulated as flowing directly to or withdrawing from a particular RCHRES as well. Water and pollutants from a given RCHRES flow into the next downstream RCHRES. The network of RCHRESs is constructed to mirror the configuration of the stream segments found in the physical world. Therefore, activities simulated in one impaired stream segment affect the water quality downstream in the model.

4.2 Model Setup

To adequately represent the spatial variation in the watershed, the James River – Lower Piedmont Region drainage area was divided into 31 subwatersheds for the purpose of modeling hydrology. The 9 most downstream subwatersheds were not part of the James River – Lower Piedmont Region TMDL study but rather from another study that was conducted simultaneously to address the bacterial TMDL needs in the James River – City of Richmond region. Those 9 subwatersheds were only used for the sake of hydrology calibration of the model since the most appropriate USGS stream flow station was located within the James River - City of Richmond region. Figure 4.1 shows the 22 subwatersheds within the James River – Lower Piedmont Region. The rationale for choosing these subwatersheds was based on the availability of water quality data and the limitations of the HSPF model. Water quality data (*i.e.,* fecal coliform concentrations) are available at specific locations throughout the watershed. Subwatershed outlets were chosen to coincide with these monitoring stations, since output from the model can only be obtained at the modeled subwatershed outlets (Figure 4.1 and Table 4.1). In an effort to standardize modeling efforts across the state, VADEQ has required that fecal bacteria models be run at a 1-hour time-step. The HSPF model requires that the time of concentration in any subwatershed be greater than the time-step being used for the model. These modeling constraints as well as the desire to maintain a spatial distribution of watershed characteristics and associated parameters were considered in the delineation of subwatersheds. The spatial division of the watersheds allowed for a more refined representation of pollutant sources, and a more realistic description of hydrologic factors in the watersheds.

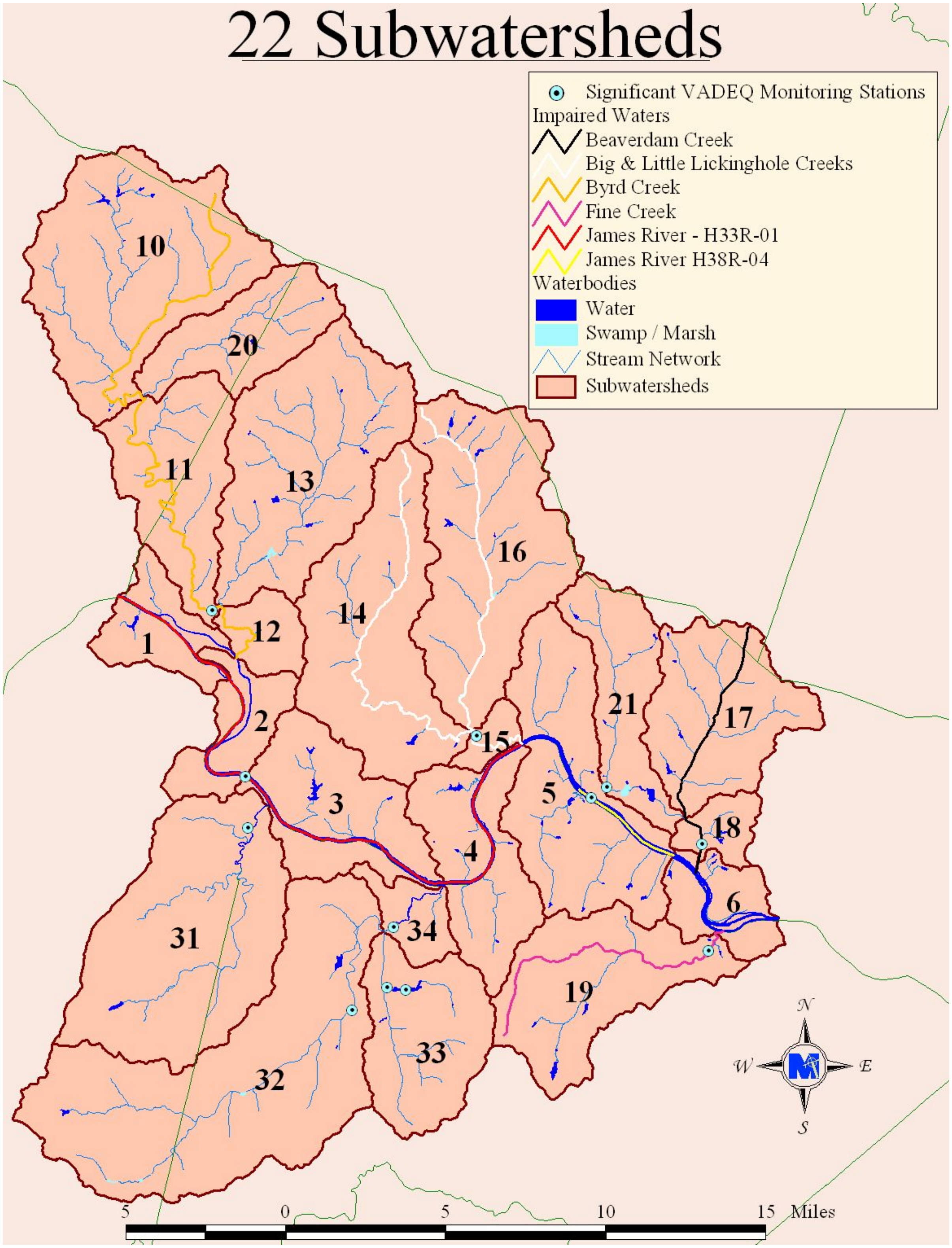

Figure 4.1 Subwatersheds delineated for modeling and location of VADEQ Water Quality Monitoring Stations and USGS Gaging Stations in the James River – Lower Piedmont Region.

Table 4.1 VADEQ Monitoring Stations and corresponding reaches in the James River – Lower Piedmont Region.

Impairment	Station Number	Reach Number
Byrd Creek	2-BYR003.35	11
Beaverdam Creek	2-BDC000.79	18
Fine Creek	2-FIN000.81	19
Big & Little Lickinghole Creek	2-BLG002.60	Below confluence of 14 & 16
Deep Creek (not impaired)	2-DCR003.00	Below confluence of 32 & 33
James River	2-JMS157.28	2

Using aerial photographs, MRLC identified 14 land use types in the watersheds. The 14 land use types were consolidated into nine categories based on similarities in hydrologic and waste application/production features (Table 4.2). Within each subwatershed, up to the nine land use types were represented. Each land use had parameters associated with it that described the hydrology of the area (*e.g.*, average slope length) and the behavior of pollutants (*e.g.*, fecal coliform accumulation rate). These land use types are represented in HSPF as pervious land segments (PERLNDs) and impervious land segments (IMPLNDs). Impervious areas in the watershed are represented in three IMPLND types, while there are nine PERLND types, each with parameters describing a particular land use (Table 4.2). Some IMPLND and PERLND parameters (*e.g.*, slope length) vary with the particular subwatershed in which they are located. Others vary with season (*e.g.*, upper zone storage) to account for plant growth, die-off, and removal.

Table 4.2 Consolidation of MRLC land use categories for the James River – Lower Piedmont Region.

TMDL Land use Categories	Pervious/Impervious (Percentage)	MRLC Land use Classifications (Class No.)
Water	Impervious (100%)	Open Water (11)
Residential	Pervious (80%) Impervious (20%)	Low Intensity Residential (21) High Intensity Residential (22) Urban/Recreational Grasses (85)
Commercial and Services	Pervious (60%) Impervious (40%)	Commercial/Industrial/Transportation (23)
Barren	Pervious (90%) Impervious (10%)	Quarries/Strip Mines/Gravel Pits (32) Transitional (33)
Woodland	Pervious (100%)	Deciduous Forest (41) Evergreen Forest (42) Mixed Forest (43)
Pasture	Pervious (100%)	Pasture/Hay (81)
Cropland	Pervious (100%)	Row Crops (82)
Wetlands	Pervious (100%)	Woody Wetlands (91) Emergent Herbaceous Wetlands (92)
Livestock Access	Pervious (100%)	Pasture/Hay (81)

Die-off of fecal coliform can be handled implicitly or explicitly. For land-applied fecal matter (mechanically applied and deposited directly), die-off was addressed implicitly through monitoring and modeling. Samples of collected waste prior to land application (*i.e.*, dairy waste from loafing areas) were collected and analyzed by MapTech. Therefore, die-off is implicitly accounted for through the sample analysis. Die-off occurring in the field was represented implicitly through model parameters such as the maximum accumulation and the 90% wash off rate, which were adjusted during the calibration of the model. These parameters were assumed to represent not only the delivery mechanisms, but the bacteria die-off as well. Once the fecal coliform entered the stream, the general decay module of HSPF was incorporated, thereby explicitly addressing the die-off rate. The general decay module uses a first order decay function to simulate die-off.

4.3 Source Representation

Both point and nonpoint sources can be represented in the model. In general, point sources are added to the model as a time-series of pollutant and flow inputs to the stream. Land-based nonpoint sources are represented as an accumulation of pollutants on land, where some portion is available for transport in runoff. The amount of accumulation and availability for transport vary with land use type and season. The model allows for a maximum accumulation to be specified. The maximum accumulation was adjusted seasonally to account for changes in die-off rates, which are dependent on temperature and moisture conditions. Some nonpoint sources, rather than being land-based, are represented as being deposited directly to the stream (*e.g.*, animal defecation in stream). These sources are modeled similarly to point sources, as they do not require a runoff event for delivery to the stream. Once in stream, die-off is represented by a first-order exponential equation.

Much of the data used to develop the model inputs for modeling water quality is time-dependent (*e.g.*, population). Depending on the timeframe of the simulation being run, different numbers should be used. Data representing 1998 were used for the water quality calibration period (1997-1999) and data representing 2001 were used for validation period (2000-2001). Data representing 2006 were used for the allocation runs in order to represent current conditions.

4.3.1 Point Sources

There are eighteen permitted point discharges in the James River and Tributaries – Lower Piedmont Region. All but one of these facilities are permitted for fecal control, with design discharges ranging from 0.001-0.465 MGD Table 3.2. The design flow capacity was used for allocation runs. This flow rate was combined with a fecal coliform concentration of 200 cfu/100 ml to ensure that compliance with state water quality standards could be met even if permitted loads were at maximum levels. For calibration and current condition runs, a lower value of fecal coliform concentration was used, based upon a regression analysis relating Total Residual Chlorine (TRC) levels and fecal coliform concentrations. Eight out of the eighteen permitted point sources are Single Family Home (SFH) allowed to discharge 0.001 MGD at the geometric mean of 200 cfu/100 ml. The discharge from the SFH permits was kept constant at those values for all stages of the water quality modeling process (calibration, validation, and allocation). Nonpoint sources of pollution that were not driven by runoff (*e.g.*, direct deposition of fecal matter to the the stream by wildlife) were modeled similarly to point sources. These sources, as well as land-based sources, are identified in the following sections.

4.3.2 Private Residential Sewage Treatment

The number of septic systems in the 22 subwatersheds modeled for water quality in the James River – Lower Piedmont Region was calculated by overlaying U.S. Census Bureau data (USCB, 1990; USCB, 2000) with the watersheds to enumerate the septic systems. Each residential land use area was assigned a number of septic systems based on census data. A total of 3,363 septic systems were estimated in the James River – Lower Piedmont Region in 1998. During allocation runs, the number of households was projected to 2006, based on current growth rates (USCB, 2000) resulting in 3,837 septic systems (Table 4.3). The number of septic systems was projected to increase to 4,101 by 2009.

4.3.2.1 Failing Septic Systems

Failing septic systems were assumed to deliver all effluent to the soil surface where it was available for wash-off during a runoff event. In accordance with estimates from Raymond B. Reneau, Jr. from Virginia Tech, a 40% failure rate for systems designed and installed prior to 1964, a 20% failure rate for systems designed and installed between 1964 and 1984, and a 5% failure rate on all systems designed and installed after 1984 was used in development of the TMDLs for the James River – Lower Piedmont Region. Total septic systems in each category were calculated using U.S. Census Bureau block demographics. The applicable failure rate was multiplied by each total and summed to get the total failing septic systems per subwatershed. The fecal coliform density for septic system effluent was multiplied by the average design load for the septic systems in the subwatershed to determine the total load from each failing system. Additionally, the loads were distributed seasonally based on a survey of septic pump-out contractors to account for more frequent failures during wet months.

4.3.2.2 Uncontrolled Discharges

Uncontrolled discharges were estimated using 1990 U.S. Census Bureau block demographics. Houses listed in the Census sewage disposal category "other means" were assumed to be disposing sewage via uncontrolled discharges. Corresponding block data and subwatershed boundaries were intersected to determine an estimate of uncontrolled discharges in each subwatershed. Fecal coliform loads for each discharge were calculated based on the fecal density of human waste and the wasteload for the average size household in the subwatershed. The loadings from uncontrolled discharges were applied directly to the stream in the same manner that point sources are handled in the model.

Table 4.3 Estimated failing septic systems.

Impaired Segment	Septic Systems	Failing Septic Systems	Uncontrolled Discharges
Byrd Creek	1,493	330	36
Big & Little Lickinghole Creek	1,385	258	16
Fine Creek	813	103	7
Beaverdam Creek	1,533	268	28
James River, H33R-01	5,375	856	125
James River, H38R-03	8,480	1,363	148

4.3.2.3 Sewer System Overflows

No sewer system overflows are reported in the study area and therefore, none were modeled.

4.3.3 Livestock

Fecal coliform produced by livestock can enter surface waters through four pathways: land application of stored waste, deposition on land, direct deposition to streams, and diversion of wash-water and waste directly to streams. Each of these pathways is accounted for in the model. The amount of fecal coliform directed through each pathway was calculated by multiplying the fecal coliform density with the amount of waste expected through that pathway. Livestock numbers determined for 2006 were used for the allocation runs, while these numbers were projected back to 1998 for the calibration and 2001 for validation runs. The numbers are based on data provided by VCE, DCR, NRCS, MSWCD, PFSWCD, and TJSWCD, as well as taking into account growth rates in Powhatan and Goochland counties as determined from data reported by the Virginia Agricultural Statistics Service (VASS, 1998; VASS, 2001). For land-applied waste, the fecal coliform density measured from stored waste was used, while the density in as-excreted manure was used to calculate the load for deposition on land and to streams (Table 3.9). The use of fecal coliform densities measured in stored manure accounts for any die-off that occurs in storage. The modeling of fecal coliform entering the stream through diversion of wash-water was accounted for by the direct deposition of fecal matter to streams by cattle.

4.3.3.1 Land Application of Collected Manure

Collection of livestock manure occurs on dairy and poultry farms. The average daily waste production per month was calculated using the number of animal units, weight of animal, and waste production rate as reported in Section 3.3.4. For dairy farms, the amount of waste collected was first based on proportion of milking cows, as the milking herd represented the only cows subject to confinement and, therefore, waste collection. Second, the total amount of waste produced in confinement was calculated based on the proportion of time spent in confinement. Poultry waste production was calculated based on the population of poultry in each farm taking into consideration that poultry is confined 100% of the time. Finally, values for the percentage of loafing lot waste collected, based on data provided by SWCD representatives and local stakeholders, were used to calculate the amount of waste available to be spread on pasture and cropland (Table 3.10).

4.3.3.2 Deposition on Land

For cattle, the amount of waste deposited on land per day was a proportion of the total waste produced per day. The proportion was calculated based on the study entitled “Modeling Cattle Stream Access” conducted by the Biological Systems Engineering Department at Virginia Tech and MapTech, Inc. for VADCR. The proportion was based on the amount of time spent in pasture, but not in close proximity to accessible streams, and was calculated as follows:

Proportion = [(24 hr) – (time in confinement) – (time in stream access areas)]/(24 hr)

All other livestock (horse and sheep) were assumed to deposit all feces on pasture. The total amount of fecal matter deposited on the pasture land use type was area-weighted.

4.3.3.3 Direct Deposition to Streams

Beef cattle are the primary sources of direct deposition by livestock in the James River – Lower Piedmont Region. The amount of waste deposited in streams each day was a proportion of the total waste produced per day by cattle. First, the proportion of manure deposited in "stream access" areas was calculated based on the "Modeling Cattle Stream Access" study. The proportion was calculated as follows:

Proportion = (time in stream access areas)/(24 hr)

For the waste produced on the "stream access" land use, 30% of the waste was modeled as being directly deposited in the stream and 70% remained on the land segment adjacent to the stream. The 70% remaining was treated as manure deposited on land. However, applying it in a separate land-use area (stream access) allows the model to consider the proximity of the deposition to the stream. The 30% that was directly deposited to the stream was modeled in the same way that point sources are handled in the model.

4.3.4 Biosolids

Investigation of VDH data indicated that biosolids applications have occurred within the James River – Lower Piedmont Region Study Area. Even though the study area is not highly urbanized, the disposal of biosolids is expected to take on increasing importance due to urban populations growing in the areas were biosolids are imported from. Class B biosolids are permitted to contain up to 1,995,262 cfu/g-dry, as compared with approximately 240 cfu/g-dry for dairy waste. Records of biosolids application dates and amounts were obtained from VDH and were entered into the model as land based inputs. During both model calibration and allocation runs, biosolids were modeled as having a fecal concentration of 157,835 cfu/g, the mean value of measured biosolids concentrations observed in several years of samples supplied by VDH. Applications were modeled as being spread onto the land surface over a six hour period on the date of reported application. An assumption of proper application was made, wherein no biosolids were modeled as being spread in stream corridors.

4.3.5 Wildlife

For each species of wildlife, a GIS habitat layer was developed based on the habitat descriptions that were obtained (Section 3.3.5). An example of one of these layers is shown in Figure 4.2. This layer was overlaid with the land use layer and the resulting area was calculated for each land use in each subwatershed. The number of animals per land segment was determined by multiplying the area by the population density. Fecal coliform loads for each land segment were calculated by multiplying the wasteload, fecal coliform densities, and number of animals for each species.

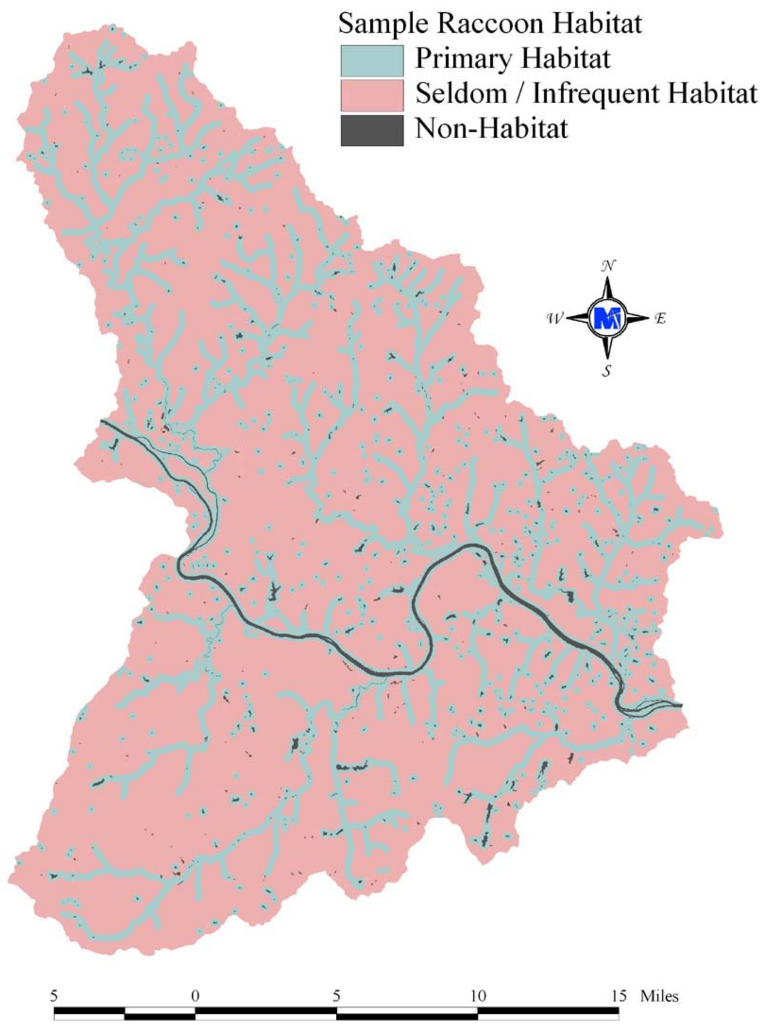

Figure 4.2 Example of raccoon habitat layer in the James River – Lower Piedmont Region, as developed by MapTech.

Based on feedback from local VDGIF and MSWCD, larger numbers of geese and duck were modeled during the water quality validation period represented by the year 1998 than the water quality validation period represented by the year 2001. Another increase was assumed for the allocation model runs as represented by the population in the year 2006. Populations of other species were assumed steady between different modeling periods. For each species, a portion of the total wasteload was considered land-based, with the remaining portion being directly deposited to streams. The portion being deposited to streams was based on the amount of time spent in stream access areas (Table 3.16). It was estimated that, for all animals other than beaver, 5% of fecal matter produced while in stream access areas was directly deposited to the stream. For beaver, it was estimated that 100% of fecal matter would be directly deposited to streams.

4.3.6 Pets

Cats and dogs were the only pets considered in this analysis. Population density (animals per house), wasteload, and fecal coliform density are reported in Section 3.3.3. Waste from pets was distributed on residential land uses. The number of households per subwatershed was taken from the 2000 Census (USCB, 1990 and USCB, 2000). The number of animals per subwatershed was determined by multiplying the number of households by the population density. The amount of fecal coliform deposited daily by pets in each subwaterhsed was calculated by multiplying the wasteload, fecal coliform density, and number of animals for both cats and dogs. The wasteload was assumed not to vary seasonally. The populations of cats and dogs were projected from 2000 data to 2006.

4.4 Stream Characteristics

HSPF requires that each stream reach be represented by constant characteristics (*e.g.*, stream geometry and resistance to flow). This data are entered into HSPF via the Hydraulic Function Tables (F-tables). The F-tables developed consist of four columns: depth (ft), area (ac), volume (ac-ft), and outflow (ft^3/s). The depth represents the possible range of flow, with a maximum value beyond what would be expected for the reach. The area listed is the surface area of the flow in acres. The volume corresponds to the total volume of the flow in the reach, and is reported in acre-feet. The outflow is simply the stream discharge, in cubic feet per second.

In order to develop the entries for the F-tables, a combination of the NRCS Regional Hydraulic Geometry Curves (NRCS, 2006) and Digital Elevation Models (DEM) was used. The NRCS has developed an empirical formula for estimating stream top width, cross-sectional area, average depth, and flow rate, all as functions of the drainage area. Estimates were obtained at the outlet of each subwatershed. Using the NRCS equations, an entry was developed in the F-table that represented a bank-full situation for the streams. However, the F-table is supposed to cover the floodplains. The floodplain information was obtained from the DEM. A profile perpendicular to the channel was generated showing the floodplain height with distance for each subwatershed outlet. An example of this profile is given in Figure 4.3. Consecutive entries to the F-table are generated by estimating the volume of water and surface area in the reach at incremental depths (where depths are taken from the outlet profile, *e.g*. Figure 4.3).

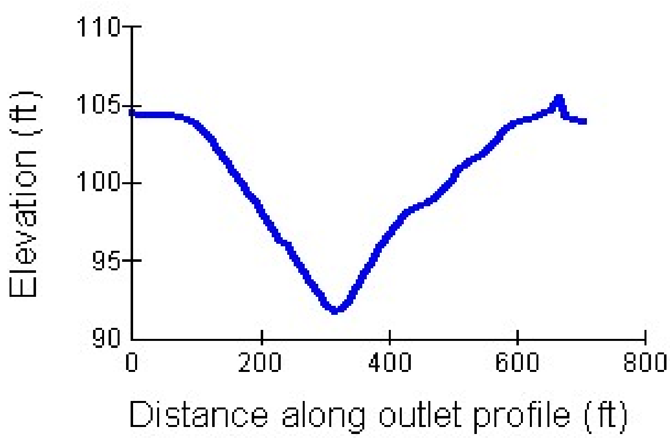

Figure 4.3 Stream profile representation in HSPF.

Conveyance was used to facilitate the calculation of discharge in the reach with values for resistance to flow (Manning's *n*) assigned based on recommendations by Brater and King (1976) and shown in Table 4.4. The conveyance was calculated for each of the two flood plains and the main channel; these figures were then added together to obtain a total conveyance. Calculation of conveyance was performed following the procedure described by Chow (1959). Average reach slope and reach length were obtained from GIS layers of the watershed, which included elevation from Digital Elevation Models (DEMs) and a stream-flow network based on National Hydrography Dataset (NHD) Data. The total conveyance was then multiplied by the square root of the average reach slope to obtain the discharge (in ft^3/s) at a given depth. An example of an F-table used in HSPF is shown in Table 4.5.

Table 4.4 Summary of Manning's roughness coefficients for channel cells*.

Section	Upstream Area (ha)	Manning's *n*
Intermittent stream	18 - 360	0.06
Perennial stream	360 and up	0.05

*Brater and King (1976)

Table 4.5 Example of an "F-table" calculated for the HSPF model.

Depth (ft)	Area (ac)	Volume (ac-ft)	Outflow (ft^3/s)
0	0	0	0
0.1	0.6	1.69	0.05
0.17	10.76	4.46	24.26
0.77	10.76	10.44	241.7
7.67	11.84	82.36	11150.2
9.59	13.64	104.21	16167.77
11.99	35.37	186.7	21029.3
14.39	36.12	270.99	38599.01
246.99	108.79	16985.15	17519166
479.6	181.45	50601.57	76135368

4.5 Selection of Representative Modeling Period

Selection of the modeling period was based on two factors: availability of data (discharge and water-quality) and the need to represent critical hydrological conditions. Mean daily discharge at USGS Gaging Station 02037500 in the James River, was available from 1934 through 2004. The timeframe for the critical period analysis was selected to include the VADEQ assessment period from July 1990 through June 2001 that led to the inclusion of the impaired streams in this TMDL study area on the 1996, 1998, 2002 and 2004 Section 303(d) lists. The fecal concentration data from this period were evaluated to determine the relationship between concentration and the level of flow in the stream. High concentrations of fecal coliform were recorded in all flow regimes, thus it was concluded that the critical hydrological condition included a wide range of wet and dry seasons.

In order to select a modeling period representative of the critical hydrological condition from the available data, the mean daily flow and precipitation for each season were calculated for the period 1934 through 2004. The results of this analysis are shown in Figures 4.4 through 4.5. This resulted in 69 observations of flow and precipitation for each season. The mean and variance of these observations were calculated. Next, a candidate period was chosen based on the availability of mean discharge data closest to the fecal coliform assessment period (July 1990 – June 2003). The representative period was chosen from this candidate period such that the mean and variance of each season in the modeled period was not significantly different from the historical data (Table 4.6). Therefore, the period was selected as representing the hydrologic regime of the study area, accounting for critical conditions associated with all potential sources within the watershed. The resulting period for hydrologic calibration was October 2000 to September 2003. For hydrologic validation, the period selected was October 1994 to September 1997.

For water quality calibration, data availability was the governing factor in the choice of calibration and validation periods. The period containing the greatest amount of monitored data dispersed over the most stations, and for which the assessment of potential sources was most accurate (October 1, 1996 to September 30, 1999), was chosen as the calibration period. This period contained 115 water quality data points spread over 6 stations. The period from October 1, 1999 to September 30, 2001 was chosen as the validation period, with 84 data points over 6 water quality sampling stations. This validation period also coincided with the representative hydrological period and therefore, the period of October 1, 1999 through September 30, 2001 was chosen as the allocation period to ensure that the critical conditions in the watershed were being simulated during water quality allocations.

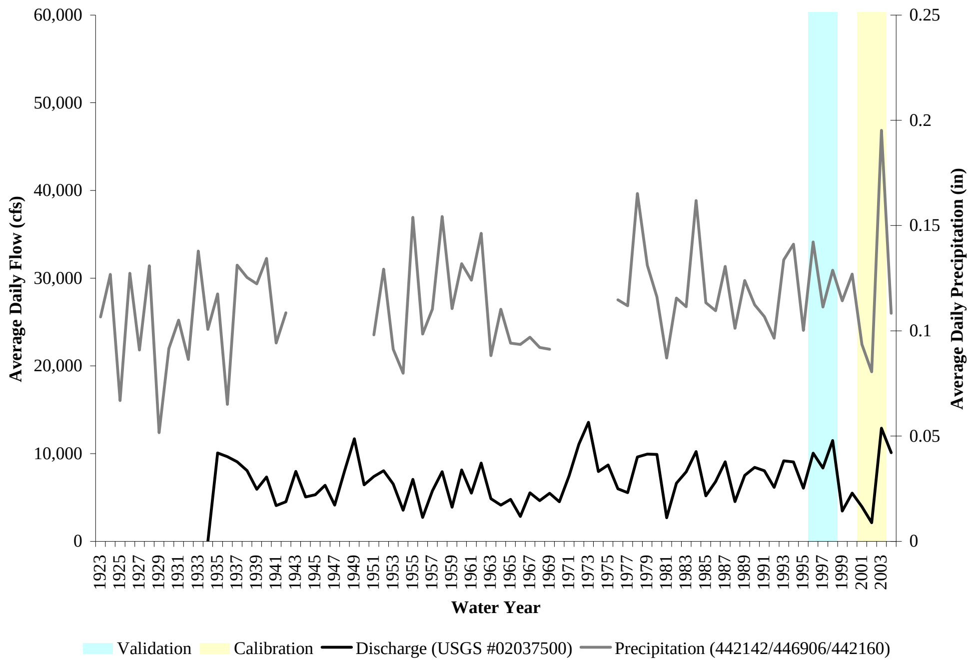

Figure 4.4 Annual Historical Flow (USGS Station 02037500) and Precipitation (Stations 442142, 446906, and 442160) Data

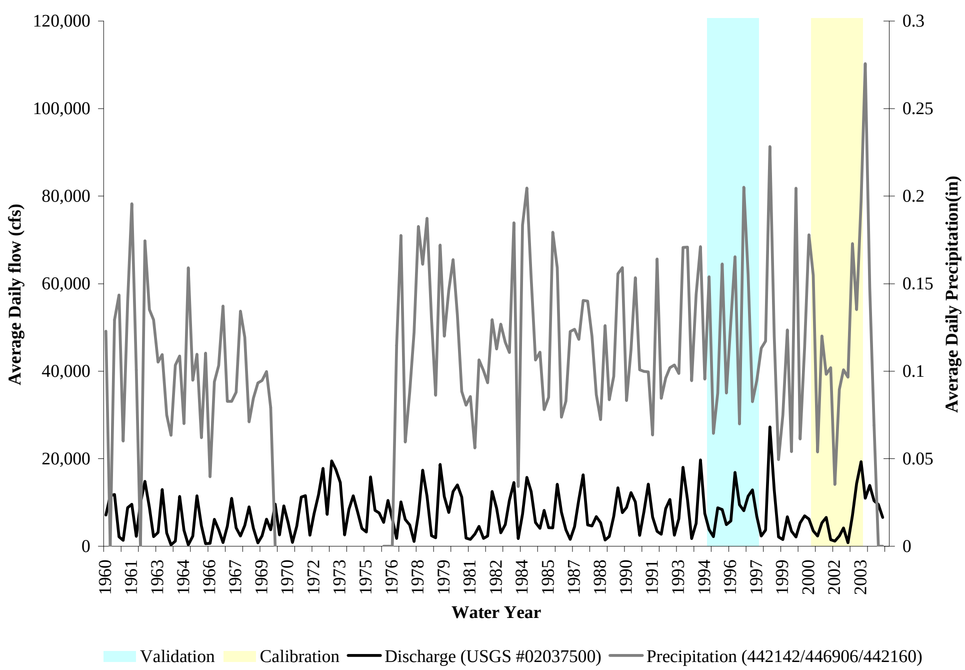

Figure 4.5 Seasonal Historical Flow (USGS Station 02037500) and Precipitation (Stations 442142, 446906, and 442160) Data

Table 4.6 Comparison of modeled period to historical records for James River and Tributaries – Lower Piedmont Region.

	Mean Daily Flow (cfs)				Precipitation (in/day)			
	USGS Station 02037500				Primary Station 442142 Secondary Stations 446906, and 442160*			
	Fall	**Winter**	**Spring**	**Summer**	**Fall**	**Winter**	**Spring**	**Summer**
	Historical Record (1923-2002)							
Mean	5,253	11,159	8,190	3,469	0.104	0.112	0.115	0.128
Variance	14,422,111	22,242,867	13,645,491	6,541,621	0.002	0.001	0.002	0.002
	Calibration & Validation Period (10/00 – 09/03, 10/94 – 09/97)							
Mean	4,995	10,080	9,119	4,785	0.102	0.113	0.120	0.147
Variance	15,227,040	31,120,023	28,200,573	16,395,295	0.003	0.001	0.002	0.006
	p-Values							
Mean	0.438	0.324	0.338	0.218	0.470	0.455	0.392	0.274
Variance	0.392	0.235	0.080	0.038	0.065	0.436	0.187	0.035

*Secondary Station utilized only when Primary Station was off-line.

4.6 Sensitivity Analysis

Sensitivity analyses are performed to determine a model's response to changes in certain parameters. This process involves changing a single parameter a certain percentage from a baseline value while holding all other parameters constant. This process is repeated for several parameters in order to gain a complete picture of the model's behavior. The information gained during sensitivity analysis can aid in model calibration, and it can also help to determine the potential effects of uncertainty in parameter estimation. Sensitivity analyses were conducted to assess the sensitivity of the model to changes in hydrologic and water quality parameters as well as to assess the impact of unknown variability in source allocation (*e.g.*, seasonal and spatial variability of waste production rates for wildlife, livestock, septic system failures, uncontrolled discharges, background loads, and point source loads).

4.6.1 Hydrology Sensitivity Analysis

The HSPF parameters adjusted for the hydrologic sensitivity analysis are presented in Table 4.7, with base values for the model runs given. The parameters were adjusted to -50%, -10%, 10%, and 50% of the base value, and the model was run for water years 2000-2003.

Where an increase of 50% exceeded the maximum value for the parameters, the maximum value was used and the parameters increased over the base value were reported. The hydrologic quantities of greatest interest in a fecal coliform model are those that govern peak flows and low flows. Peak flows, being a function of runoff, are important because they are directly related to the transport of fecal coliforms from the land surface to the stream. Peak flows were most sensitive to changes in the parameters governing infiltration such as INFILT (Infiltration), LZSN (Lower Zone Storage), and by UZSN (Upper Zone Storage), which governs surface transport, and LZETP (Lower Zone Evapotranspiration), which affects soil moisture. Low flows are important in a water quality model because they control the level of dilution during dry periods. Parameters with the greatest influence on low flows (as evidenced by their influence in the *Low Flows* and *Summer Flow Volume* statistics) were AGWRC (Groundwater Recession Rate), BASETP (Base Flow Evapotranspiration), LZETP, INFILT, DEEPFR (Groundwater Inflow to Deep Recharge), UZSN, CEPSC (Interception Storage Capacity), and LZSN. The responses of these and other hydrologic outputs are reported in Table 4.8.

Table 4.7 HSPF base parameter values used to determine hydrologic model response.

Parameter	Description	Units	Base Value
LZSN	Lower Zone Nominal Storage	in	3.421-5.966
INFILT	Soil Infiltration Capacity	in/hr	0.0316-1013
BASETP	Base Flow Evapotranspiration	---	0.1-0.1
INTFW	Interflow Inflow	---	2.0-2.0
DEEPFR	Groundwater Inflow to Deep Recharge	---	0.1-0.1
AGWRC	Groundwater Recession rate	---	0.98
KVARY	Groundwater Recession Flow	1/in	1.0
MON-INTERCEP	Monthly Interception Storage Capacity	in	0.01-0.3
MON-UZSN	Monthly Upper Zone Nominal Storage	in	0.18-0.98
MON-LZETP	Monthly Lower Zone Evapotranspiration	in	0.1-0.8

Table 4.8 HSPF Sensitivity analysis results for hydrologic model parameters for the James River.

Model Parameter	Parameter Change (%)	Percent Change In: Total Flow	High Flows	Low Flows	Winter Flow Volume	Spring Flow Volume	Summer Flow Volume	Fall Flow Volume	Total Storm Volume
AGWRC[1]	0.85	0.42	0.72	-1.32	0.46	0.04	0.10	1.76	0.46
AGWRC[1]	0.92	0.27	0.42	-1.12	0.47	0.03	-0.25	1.17	0.30
AGWRC[1]	0.96	0.12	0.16	-0.79	0.37	0.03	-0.29	0.39	0.13
AGWRC[1]	0.999	-2.81	-1.14	-4.13	-3.43	-2.31	-2.06	-3.95	-3.11
BASETP	-50	0.36	-0.02	2.13	-0.07	0.51	0.90	0.12	-0.10
BASETP	-10	0.06	0.00	0.33	-0.01	0.10	0.12	0.03	0.06
BASETP	10	-0.06	0.00	-0.29	0.01	-0.09	-0.10	-0.03	-0.06
BASETP	50	-0.24	0.02	-1.19	0.04	-0.39	-0.40	-0.14	-0.24
DEEPFR	-50	0.31	0.11	0.68	0.32	0.25	0.30	0.45	0.34
DEEPFR	-10	0.06	0.02	0.14	0.06	0.05	0.06	0.09	0.07
DEEPFR	10	-0.06	-0.02	-0.13	-0.06	-0.05	-0.06	-0.09	-0.07
DEEPFR	50	-0.31	-0.11	-0.67	-0.32	-0.25	-0.30	-0.45	-0.34
INFILT	-50	0.24	0.53	-1.27	0.31	-0.12	0.59	0.61	0.27
INFILT	-10	0.04	0.09	-0.26	0.06	-0.02	0.07	0.10	0.04
INFILT	10	-0.03	-0.08	0.25	-0.06	0.02	-0.06	-0.09	-0.04
INFILT	50	-0.13	-0.37	1.17	-0.26	0.09	-0.22	-0.42	-0.24
INTFW	-50	0.01	0.07	-0.06	0.06	-0.13	0.22	-0.02	0.02
INTFW	-10	0.00	0.00	0.00	0.01	-0.02	0.04	0.00	0.00
INTFW	10	0.00	0.00	-0.01	-0.01	0.02	-0.04	0.00	0.00
INTFW	50	-0.02	0.01	-0.03	-0.05	0.07	-0.19	0.01	-0.02
LZSN	-50	0.54	0.36	0.17	0.88	0.28	-0.49	1.93	0.60
LZSN	-10	0.08	0.07	-0.05	0.14	0.05	-0.09	0.29	0.09
LZSN	10	-0.08	-0.07	0.07	-0.13	-0.05	0.08	-0.25	-0.09
LZSN	50	-0.34	-0.32	0.41	-0.56	-0.25	0.32	-1.00	-0.38
KVARY	-50	-0.05	-0.13	0.38	-0.12	0.00	0.10	-0.28	-0.06
KVARY	-10	-0.01	-0.02	0.06	-0.02	0.00	0.01	-0.05	-0.01
KVARY	10	0.01	0.02	-0.05	0.02	0.00	-0.01	0.04	0.01
KVARY	50	0.05	0.11	-0.18	0.07	0.00	-0.01	0.20	0.05
CEPSC	-50	0.23	0.07	0.73	0.08	0.26	0.38	0.27	0.26
CEPSC	-10	0.04	0.01	0.09	0.01	0.04	0.07	0.04	0.04
CEPSC	10	-0.04	-0.01	-0.09	-0.01	-0.05	-0.06	-0.04	-0.04
CEPSC	50	-0.18	-0.05	-0.48	-0.07	-0.22	-0.24	-0.21	-0.20
LZETP	-50	1.28	0.32	4.49	1.16	0.29	2.16	3.06	0.68
LZETP	-10	0.25	0.06	0.85	0.23	0.06	0.39	0.62	0.27
LZETP	10	-0.24	-0.06	-0.82	-0.24	-0.06	-0.36	-0.59	-0.25
LZETP	50	-0.89	-0.23	-2.95	-0.94	-0.28	-1.12	-2.18	-0.97
UZSN	-50	0.83	0.53	1.26	0.55	0.28	1.81	1.60	0.92
UZSN	-10	0.13	0.09	0.17	0.09	0.03	0.26	0.29	0.14
UZSN	10	-0.12	-0.09	-0.14	-0.09	-0.03	-0.23	-0.27	-0.13
UZSN	50	-0.51	-0.39	-0.61	-0.42	-0.11	-0.94	-1.22	-0.55

[1]Actual parameter value used

4.6.2 Water Quality Parameter Sensitivity Analysis

For the water quality sensitivity analysis, an initial base run was performed using precipitation data from water years 1997 through 1999, and model parameters established for 2006 conditions (see section 4.5 for a complete explanation of selected model time periods). The three HSPF parameters impacting the model's water quality response (Table 4.9) were increased and decreased by amounts that were consistent with the range of values for the parameter. The First Order Decay (FSTDEC) was the parameters with the greatest influence on monthly geometric mean concentration (Table 4.10). The reason behind the more pronounced impact of change in decay rate on concentration of bacteria in the stream is that changes in decay rate impact both incoming bacteria load from upstream area as well as bacteria load from within the study area. On the other hand, changes in maximum fecal coliform accumulation on the land (MON-SQOLIM) and wash-off rate for fecal coliform on land surface (WSQOP) only impact the study area, and since there is a considerable load of bacteria coming in from upstream area that is not modeled here, the resulting change in fecal coliform concentration is relatively small compared to the concentration coming in from upstream area. Graphical depictions of the results of this sensitivity analysis can be seen in Figures 4.6 through 4.11.

Table 4.9 Base parameter values used to determine water quality model response.

Parameter	Description	Units	Base Value
MON-SQOLIM	Maximum FC Accumulation on Land	FC/ac	0 - 5.1E+13
WSQOP	Wash-off Rate for FC on Land Surface	in/hr	1
FSTDEC	In-stream First Order Decay Rate	1/day	1

Table 4.10 Percent change in average monthly *E. coli* geometric mean for the years 1997-1999 for James River at outlet of study area (subshed 6).

Model	Parameter Change	Percent Change in Average Monthly *E. coli* Geometric Mean for 1993-1997											
Parameter	(%)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
FSTDEC	-50	61.68	65.71	69.23	62.43	65.61	65.03	70.23	75.08	77.61	73.20	75.45	69.54
FSTDEC	-10	9.73	10.27	10.36	9.77	10.15	10.04	10.65	11.33	11.51	10.97	11.15	10.49
FSTDEC	10	-8.74	-9.18	-9.15	-8.75	-9.04	-8.94	-9.41	-9.98	-10.08	-9.65	-9.78	-9.28
FSTDEC	50	-35.84	-37.32	-36.70	-35.74	-36.66	-36.26	-37.67	-39.73	-39.80	-38.38	-38.76	-37.22
SQOLIM	-50	-2.08	-0.12	-5.12	-2.91	-1.82	-0.96	-1.42	-2.70	-0.45	-1.07	-4.23	-5.47
SQOLIM	-25	-0.94	-0.05	-2.22	-1.18	-0.80	-0.45	-0.69	-1.29	-0.19	-0.46	-1.80	-2.49
SQOLIM	25	0.79	0.06	2.03	0.95	0.62	0.41	0.64	1.19	0.15	0.35	1.35	2.06
SQOLIM	50	1.48	0.11	3.85	1.70	1.10	0.76	1.22	2.25	0.26	0.63	2.46	3.82
WSQOP	-50	1.70	0.13	6.72	4.32	2.74	1.41	1.79	1.70	0.31	1.18	3.10	5.30
WSQOP	-10	0.26	0.02	0.96	0.60	0.35	0.17	0.22	0.28	0.04	0.13	0.44	0.74
WSQOP	10	-0.24	-0.01	-0.85	-0.53	-0.30	-0.14	-0.19	-0.25	-0.03	-0.11	-0.39	-0.64
WSQOP	50	-0.99	-0.06	-3.46	-2.12	-1.17	-0.52	-0.73	-1.07	-0.10	-0.40	-1.67	-2.57

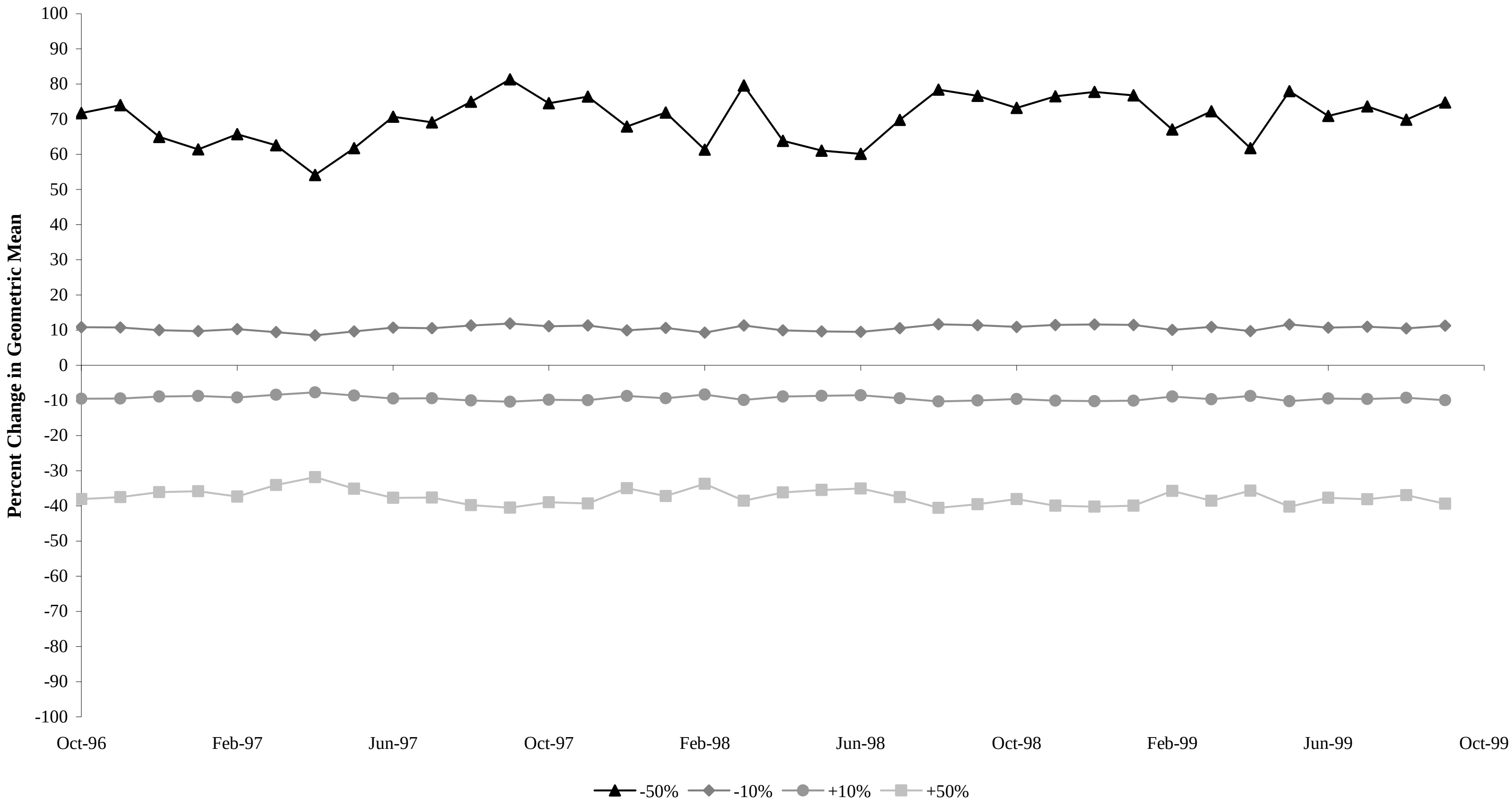

Figure 4.6 Results of sensitivity analysis on monthly geometric-mean concentrations at outlet of James River within the study area (subshed 6), as affected by changes in the in-stream first-order decay rate (FSTDEC).

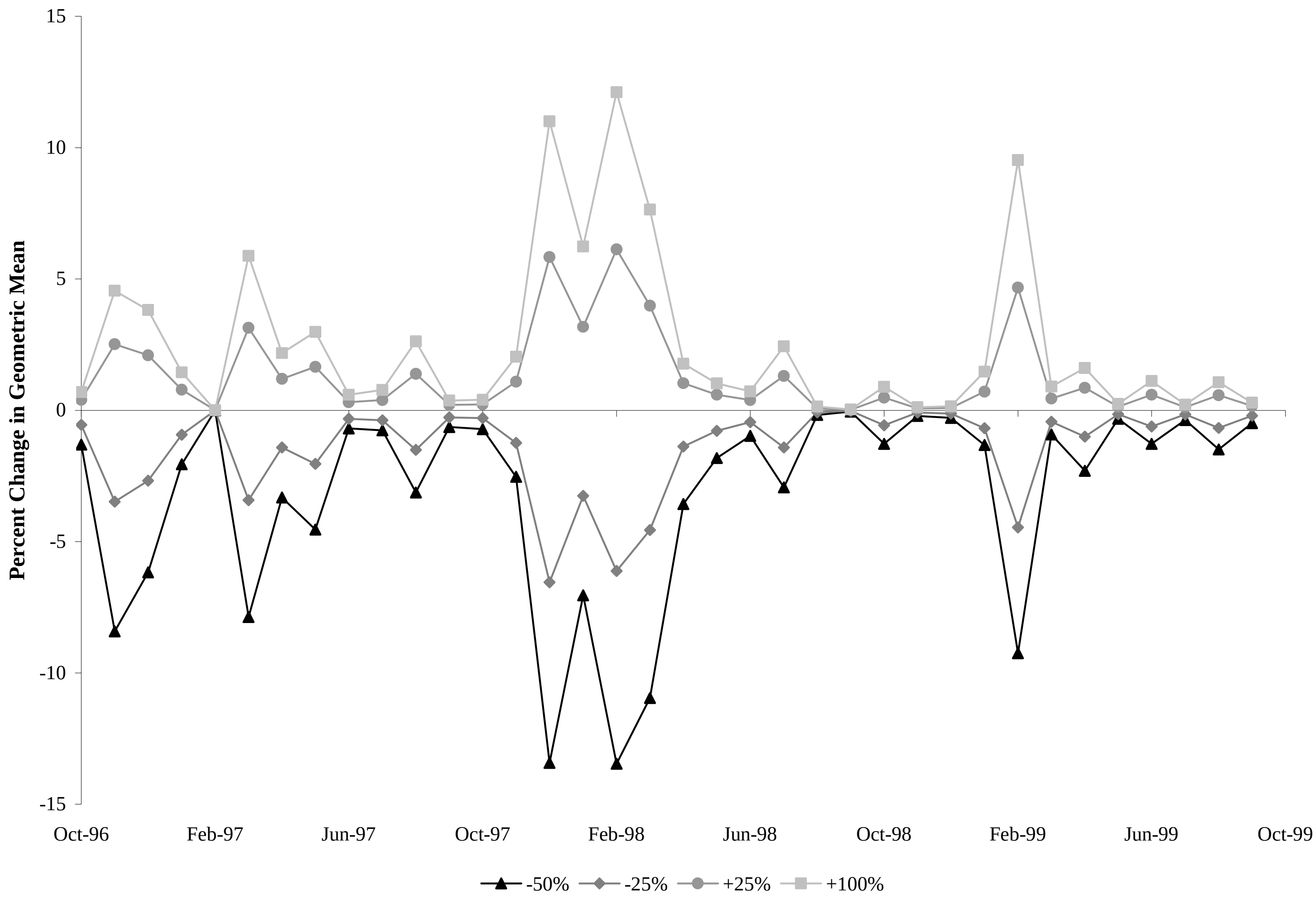

Figure 4.7 **Results of sensitivity analysis on monthly geometric-mean concentrations at outlet of James River within the study area (subshed 6), as affected by changes in maximum fecal accumulation on land (MON-SQOLIM).**

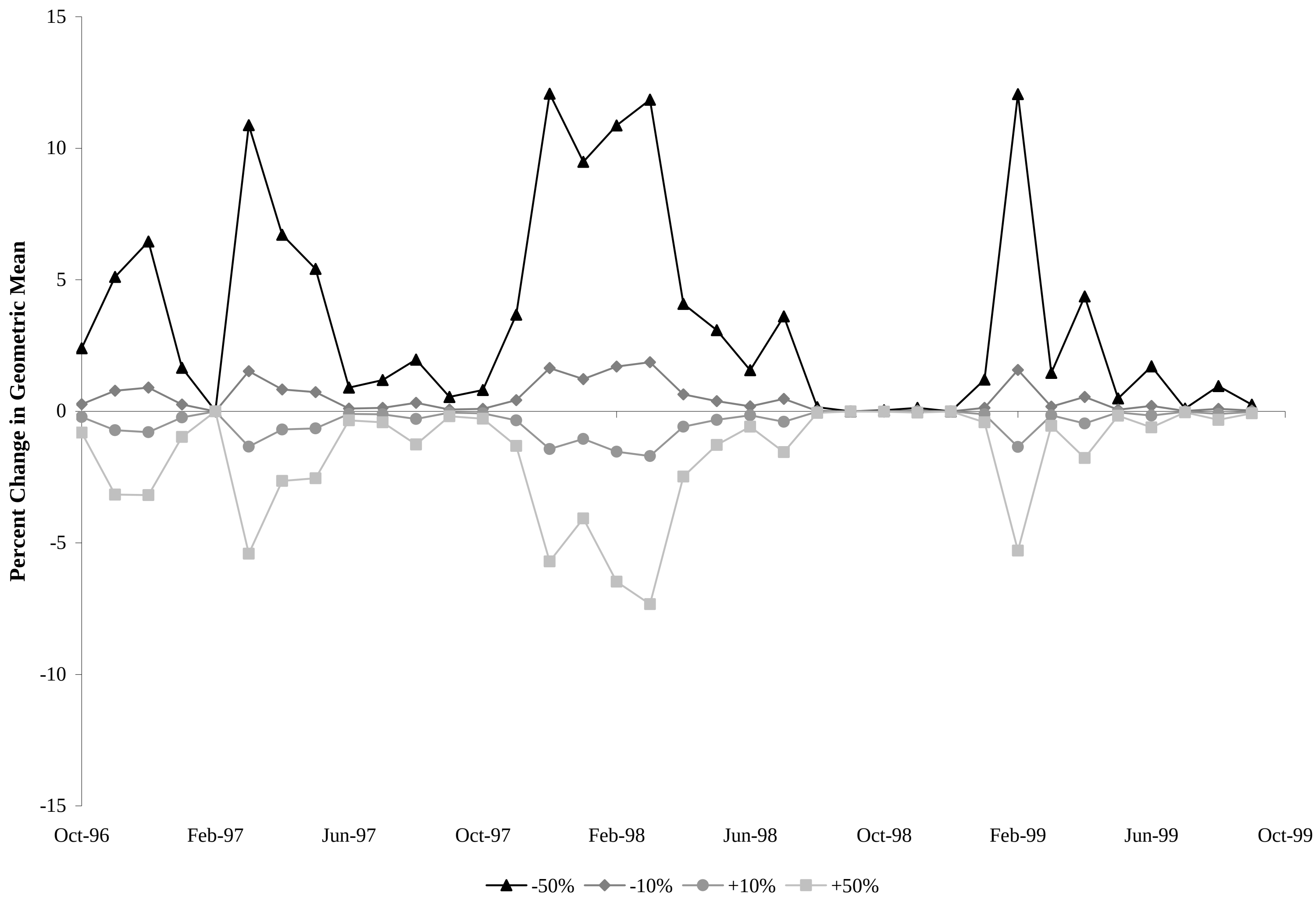

Figure 4.8 **Results of sensitivity analysis on monthly geometric-mean concentrations at outlet of James River within the study area (subshed 6), as affected by changes in the wash-off rate from land surfaces (WSQOP).**

In addition to analyzing the sensitivity of the model response to changes in water quality transport and die-off parameters, the response of the model to changes in land-based and direct loads was also analyzed. It is evident in Figure 4.9 that the model predicts a linear relationship between increased fecal coliform concentrations in both land and direct applications, and total load reaching the stream. The magnitude of this relationship differs greatly between land applied and direct loadings; a 100% increase in the land applied loads results in an increase of about 3% in stream loads, while a 100% increase in direct loads results in less than a 0.3% increase in stream loads. Both direct loads and land applied loads have a significant impact on the geometric mean concentrations (Figures 4.10 and 4.11).

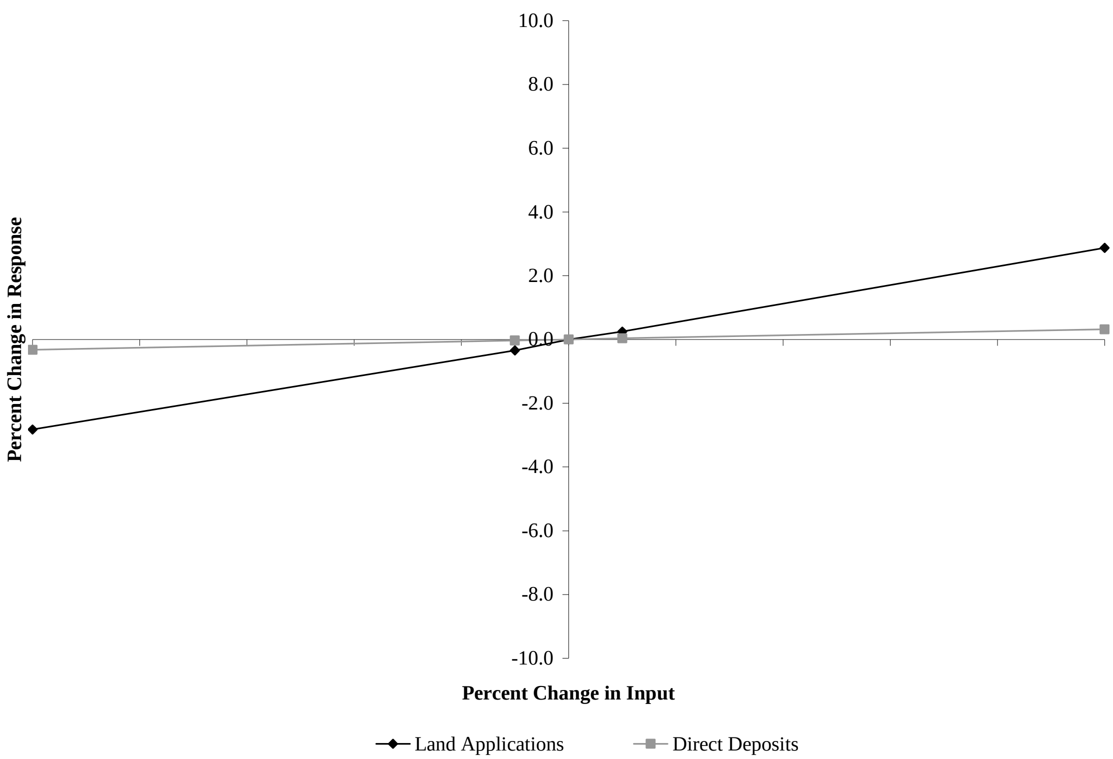

Figure 4.9 Results of total loading sensitivity analysis for outlet of James River within the study area.

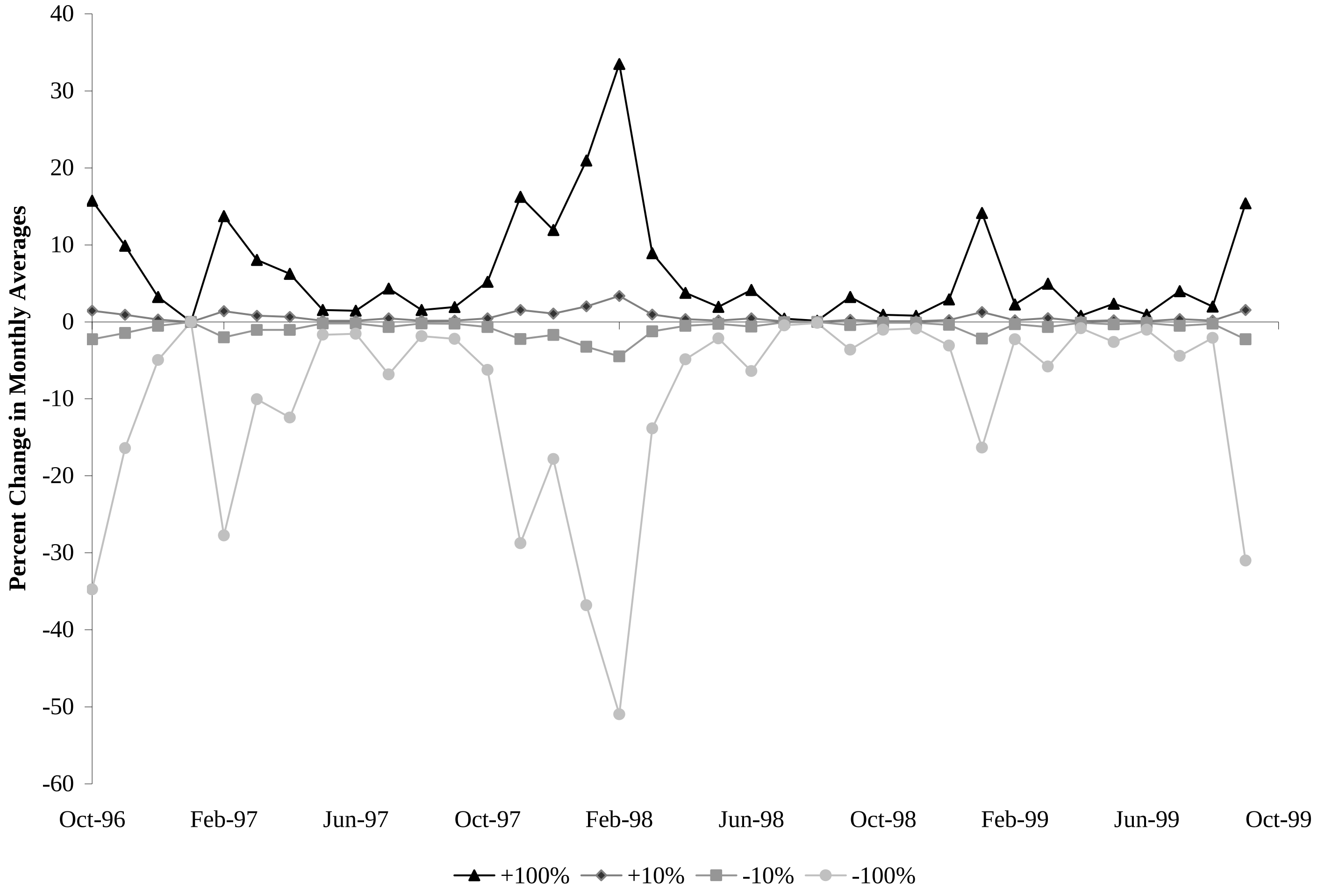

Figure 4.10 **Results of sensitivity analysis on monthly geometric-mean concentrations in James River within study area, as affected by changes in land-based loadings.**

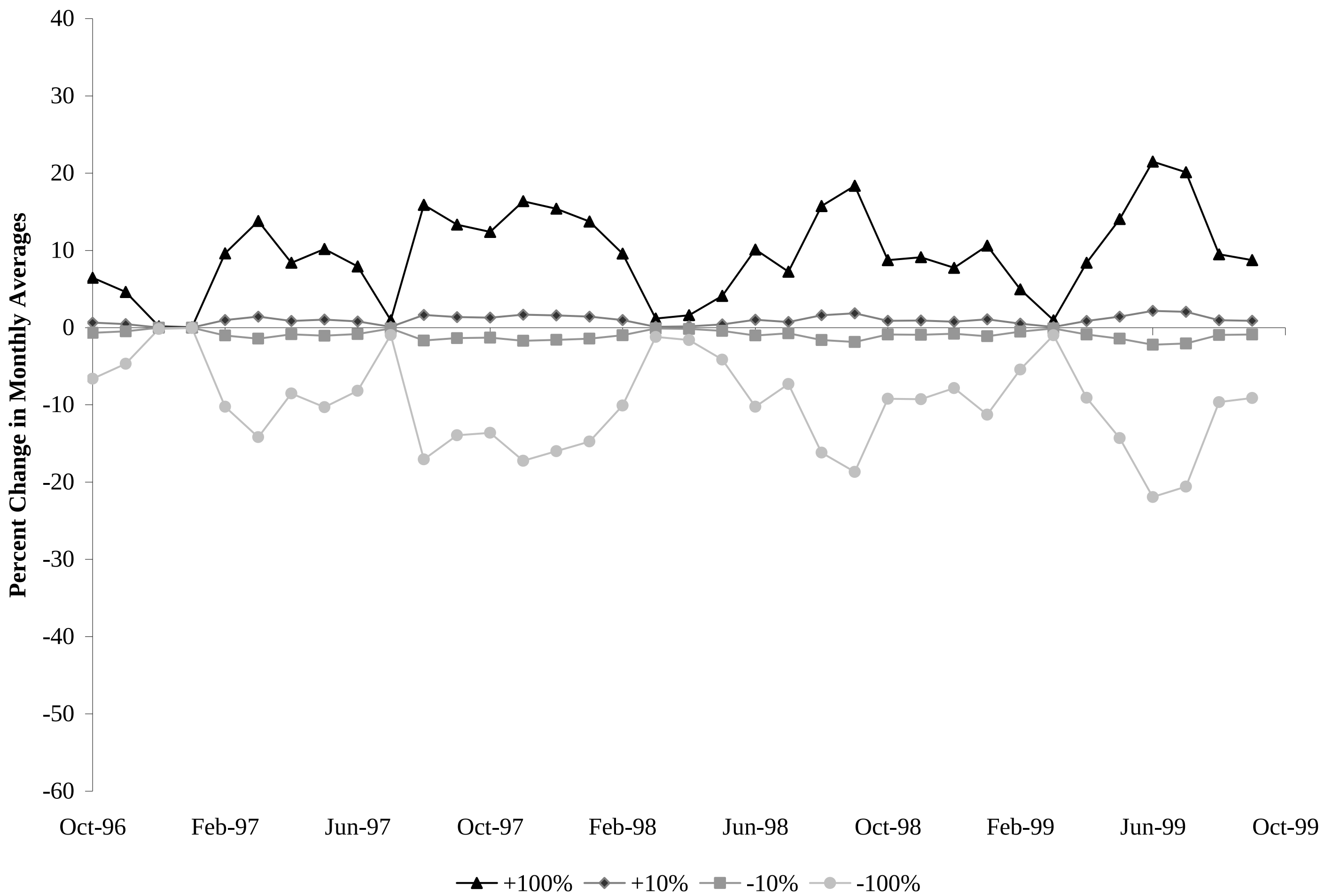

Figure 4.11 Results of sensitivity analysis on monthly geometric-mean concentrations in James River within study area, as affected by changes in loadings from direct nonpoint sources.

4.7 Model Calibration and Validation Processes

Calibration and validation are performed in order to ensure that the model accurately represents the hydrologic and water quality processes in the watershed. The model's hydrologic parameters were set based on available soils, land use, and topographic data. Through calibration, these parameters were adjusted within appropriate ranges until the model performance was deemed acceptable.

4.7.1 Hydrologic Calibration and Validation

HSPF parameters that were adjusted during the hydrologic calibration represented: the amount of evapotranspiration from the root zone (LZETP), the recession rates for groundwater (AGWRC) and interflow (IRC), the amount of soil moisture storage in the upper zone (UZSN) and lower zone (LZSN), the amount of interception storage (CEPSC), the infiltration capacity (INFILT), the amount of soil water contributing to interflow (INTFW), deep groundwater inflow fraction (DEEPER), baseflow PET (BASETP), forest coverage (FOREST), groundwater recession flow (KVARY), maximum and minimum air temperature affecting PET (PETMAX, PETMIN, respectively), infiltration equation exponent (INFEXP), infiltration capacity ratio (INFILD), active groundwater storage PET (AGWETP), and interception (RETSC). Table 4.11 contains the possible range for the above parameters along with the initial estimate and final calibrated value. State variables in the PERLND water (PWAT) section of the User's Control Input (UCI) file were adjusted to reflect initial conditions.

The model was calibrated for hydrologic accuracy using daily flow data from USGS Gaging Station 02037500 on the James River for the period October 2000 through September 2003 (Table 4.12). Figures 4.12 and 4.13 display comparisons of modeled versus observed data for the entire calibration period.

NCDC weather stations Crozier (442142), Powhatan (446906), and Cumberland (442160) were used to supply precipitation input for the HSPF model. For the entire modeling period, only daily precipitation values were available, thus daily rainfall values were interpolated to hourly values in order to provide model input on an hourly basis. This interpolation was performed in an HSPF utility called WDMUtil, and is referred to as disaggregation. In this process, a daily rainfall total is divided up into hourly values using a representative distribution scheme. Daily values were disaggregated using two different schemes: 1) a station matching disaggregation scheme and 2) a triangular disaggregation scheme. The station matching procedure involved identifying a rain gage reporting hourly data in close proximity to the James River – Lower Piedmont Region whose daily total precipitation was within 5% of the total daily precipitation value of a station within the study area. In this case, the distribution of rainfall at the station within the watershed was disaggregated based on the precipitation pattern reported at the hourly station. When this condition failed, the precipitation was disaggregated based on a triangular distribution, over an 8-hour period.

Table 4.11 Model parameters utilized for hydrologic calibration.

Parameter	Units	Possible Range of Parameter Value	Initial Parameter Estimate	Calibrated Parameter Value
LZSN	in	2.0 – 15.0	0.0-12.64	3.42-5.97
INFILT	in/hr	0.001 – 0.50	0.05-0.37	0.0316-0.1013
LSUR	ft	100 – 700	0.0-700	2.8-700
SLSUR	---	0.001 – 0.30	0.0-0.05	0.0223-0.3045
KVARY	l/in	0.0 – 5.0	0.0	0.0
AGWRC	l/day	0.85 – 0.999	0.98	0.996 – 0.996
PETMAX	degF	32.0 – 48.0	40.0	40.0
PETMIN	degF	30.0 – 40.0	35.0	35.0
INFEXP	---	1.0 – 3.0	2.0	2.0
INFILD	---	1.0 – 3.0	2.0	2.0
DEEPFR	---	0.0 – 0.50	0.01	0.2 – 0.2
BASETP	---	0.0 – 0.20	0.01	0.145– 0.145
AGWETP	---	0.0 – 0.20	0.0	0.00 – 0.01
CEPSC	in	0.01 - 0.40	0.0 – 0.2	0.0 – 0.3
UZSN	in	0.05 – 2.0	0.0–1.647	0.36– 1.94
NSUR	---	0.10 – 0.50	0.001 – 0.6	0.05 – 0.37
INTFW	---	1.0 – 10.0	1	1.0 – 1.0
IRC	l/day	0.30 – 0.85	0.50	0.3 – 0.3
LZETP	---	0.1 – 0.9	0.0 – 0.8	0.01 – 0.8
RETSC	in	0.0 – 1.0	0.1	0.1
KS	---	0.0 – 0.9	0.5	0.5

Table 4.12 Hydrology calibration criteria and model performance for period 10/1/2000 through 9/30/2003 at USGS Gaging Station 02037500 on James River.

Criterion	Observed	Modeled	Error
Total In-stream Flow:	4219.72	4397.74	4.22%
Upper 10% Flow Values:	1924.65	1920.53	-0.21%
Lower 50% Flow Values:	493.84	542.90	9.93%
Winter Flow Volume	1209.05	1217.33	0.68%
Spring Flow Volume	1670.22	1744.40	4.44%
Summer Flow Volume	747.66	822.81	10.05%
Fall Flow Volume	592.79	613.21	3.45%
Total Storm Volume	3882.51	3944.95	1.61%
Winter Storm Volume	1125.55	1105.37	-1.79%
Spring Storm Volume	1585.79	1631.19	2.86%
Summer Storm Volume	663.74	709.61	6.91%
Fall Storm Volume	507.43	498.77	-1.71%

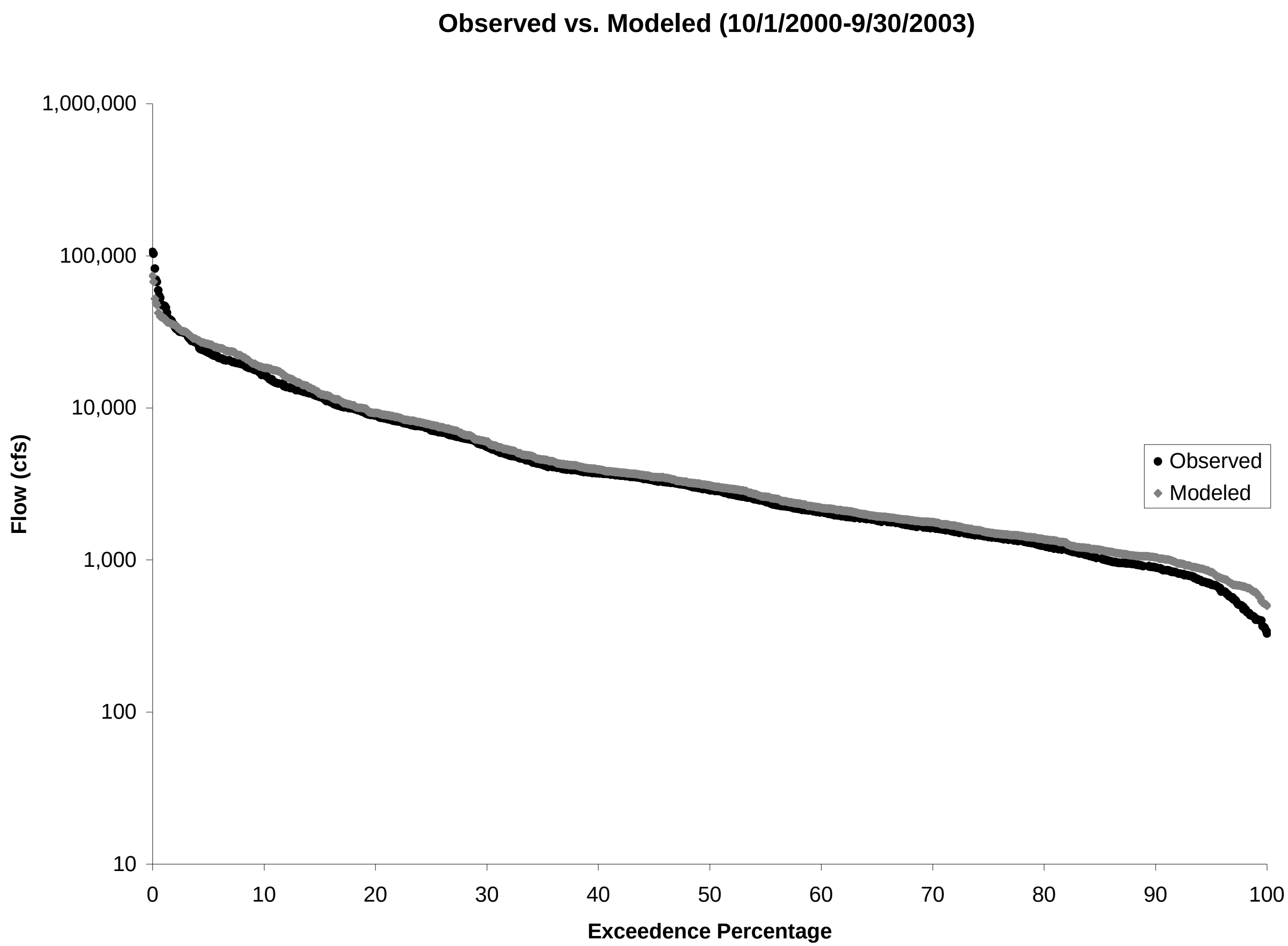

Figure 4.12 James River flow duration at USGS Gaging Station 02037500 for calibration period 10/1/2000 through 9/30/2003.

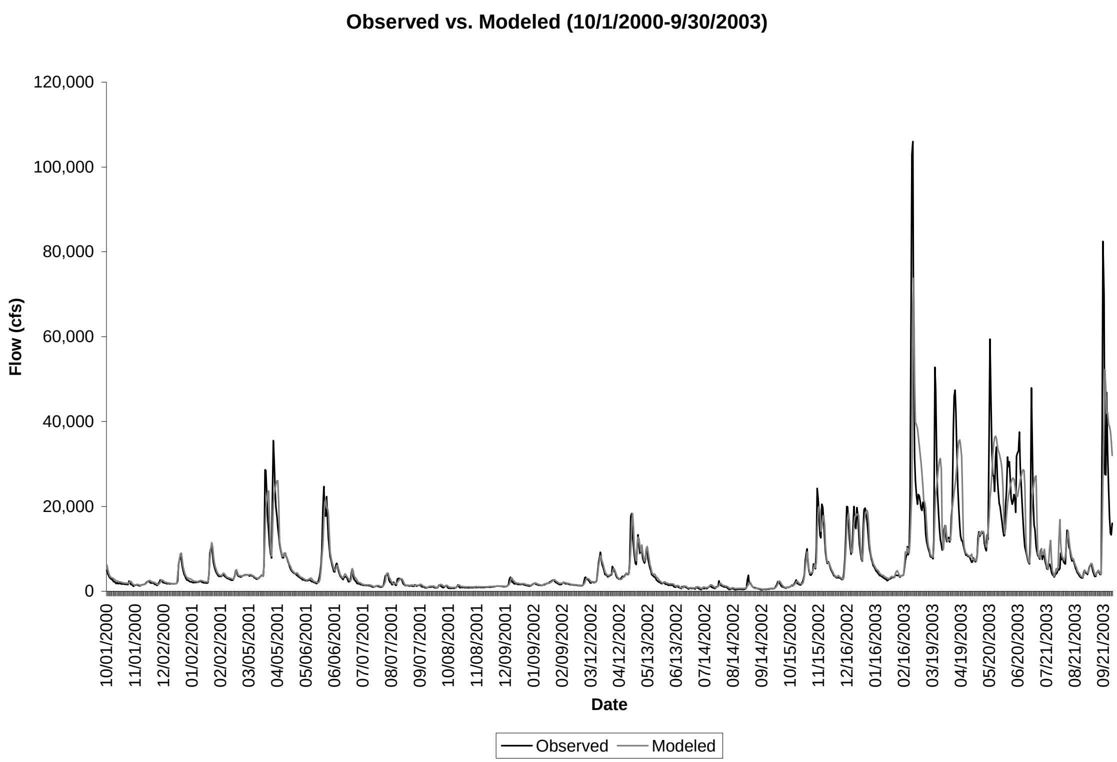

Figure 4.13 Calibration results for calibration period 10/1/2000 through 9/30/2003 at USGS Gaging Station 02037500.

4.7.2 HSPF Hydrologic Validation

The hydrologic model was verified using stream flow data from 10/1/1994 to 9/30/1997. The resulting statistics are shown in Table 4.13. The percent error is within acceptable ranges for model validation. The hydrology validation results are shown in Figures 4.14 and 4.15.

Table 4.13 Hydrology validation criteria and model performance for Slate River for the period 10/01/1994 through 9/30/1997.

Criterion	Observed	Modeled	Error
Total In-stream Flow:	5357.83	5783.86	7.95%
Upper 10% Flow Values:	1996.11	2029.07	1.65%
Lower 50% Flow Values:	1008.10	1115.68	10.67%
Winter Flow Volume	2035.81	2165.92	6.39%
Spring Flow Volume	1411.33	1397.74	-0.96%
Summer Flow Volume	847.51	1034.40	22.05%
Fall Flow Volume	1063.18	1185.80	11.53%
Total Storm Volume	4449.23	4802.54	7.94%
Winter Storm Volume	1810.50	1922.54	6.19%
Spring Storm Volume	1184.35	1152.64	-2.68%
Summer Storm Volume	620.69	789.29	27.16%
Fall Storm Volume	833.70	938.00	12.51%

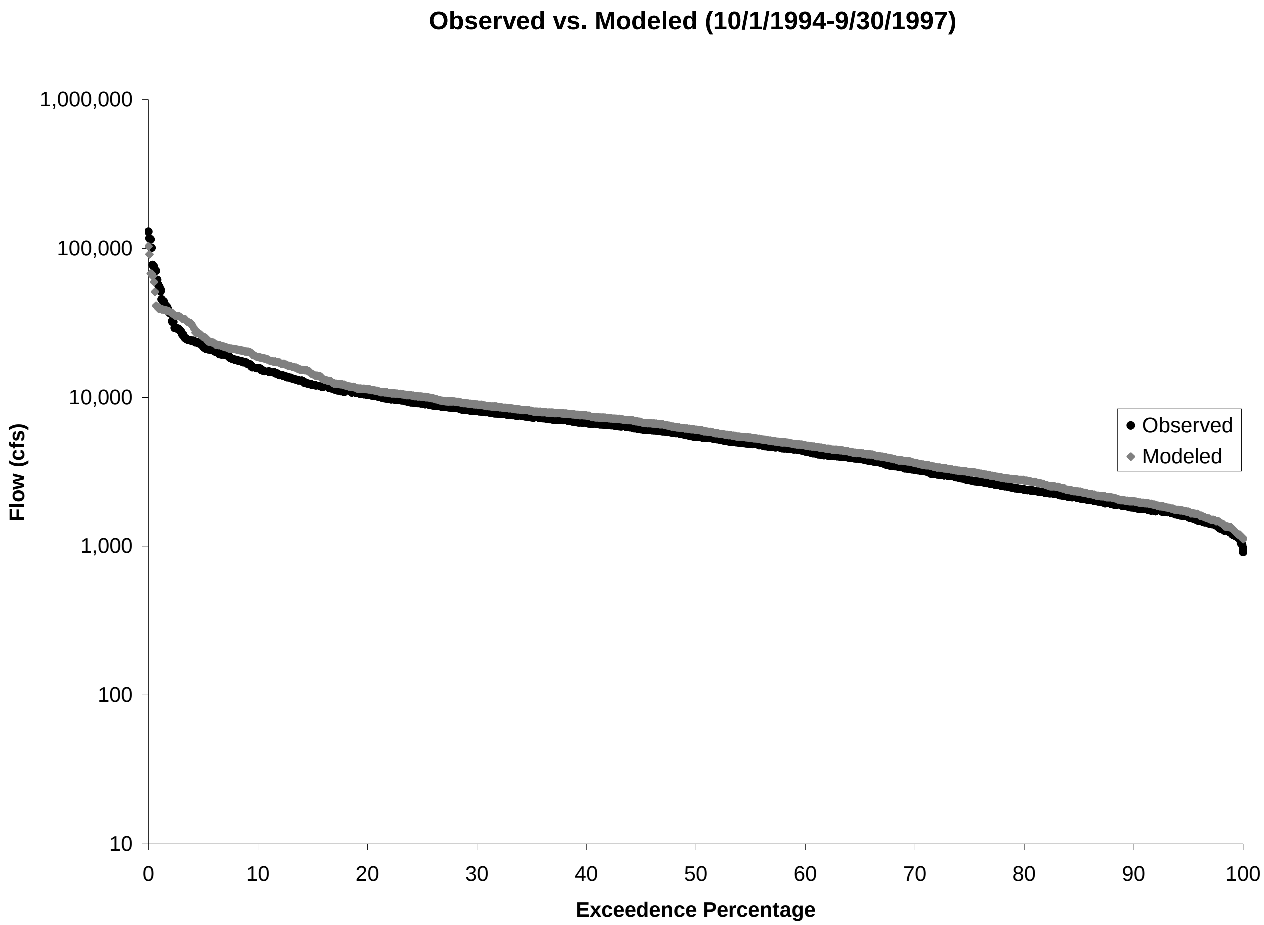

Figure 4.14 James River flow duration (10/01/1994 through 09/30/1997).

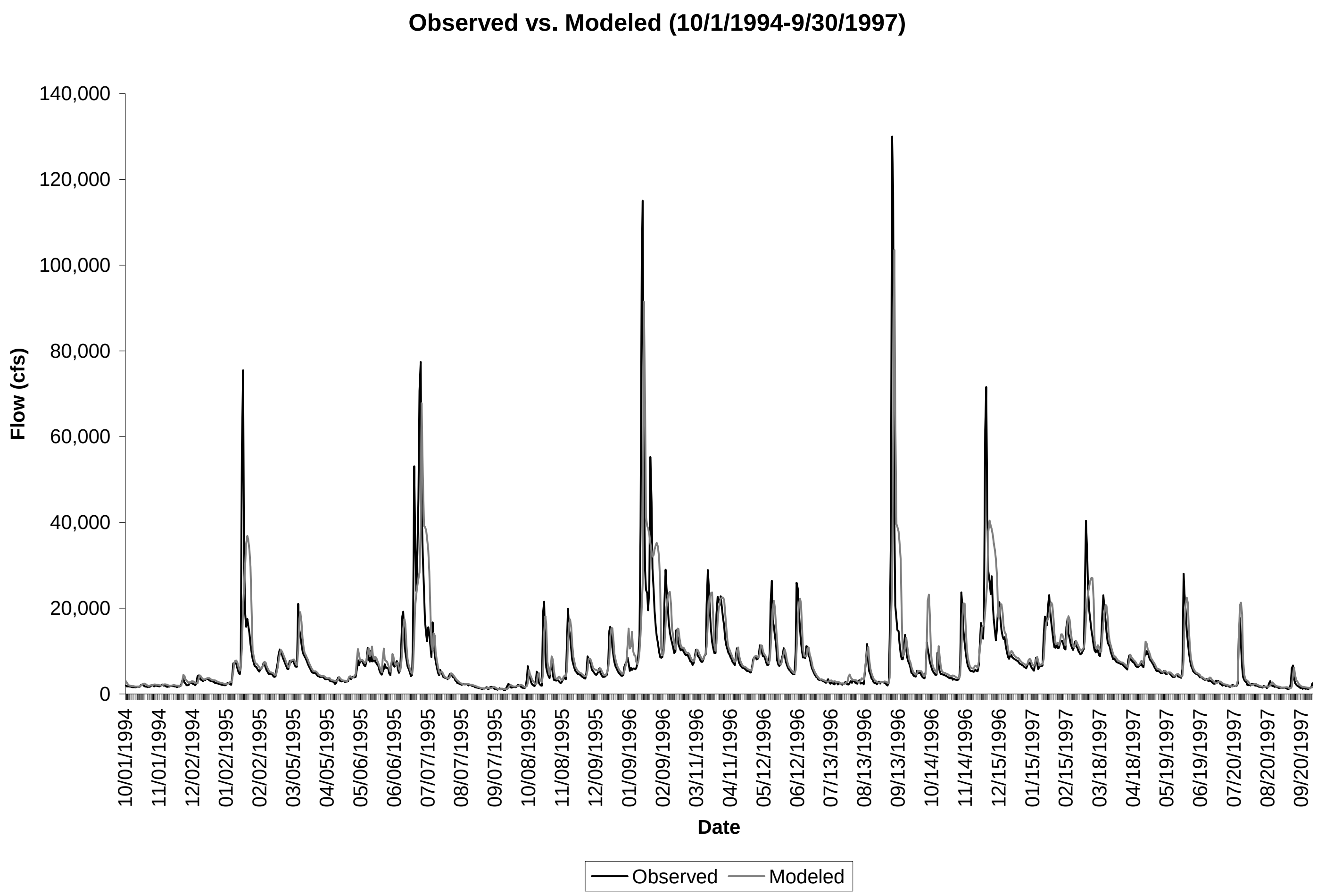

Figure 4.15 Hydrology validation results for James River (10/01/1994 through 09/30/1997).

4.7.3 Water Quality Calibration and Validation

Water quality calibration is complicated by a number of factors, some of which are described here. First, water quality concentrations (*e.g.*, fecal coliform concentrations) are highly dependent on flow conditions. Any variability associated with the modeling of stream flow compounds the variability in modeling water quality parameters such as fecal coliform concentration. Second, the concentration of fecal coliform is particularly variable. Variability in location and timing of fecal deposition, variability in the density of fecal coliform bacteria in feces (among species and for an individual animal), environmental impacts on re-growth and die-off, and variability in delivery to the stream all lead to difficulty in measuring and modeling fecal coliform concentrations. Additionally, the maximum values were at times censored at 8,000 cfu/100ml and, at other times, at 16,000 cfu/100ml. Limited amount of measured data for use in calibration and the practice of censoring both high (8,000 or 16,000 cfu/100 ml) and low (under 100 cfu/100 ml) concentrations impede the calibration process.

The water quality calibration was conducted from 10/1/1996 through 9/30/1999. Three parameters were utilized for model adjustment: in-stream first-order decay rate (FSTDEC), maximum accumulation on land (SQOLIM), and rate of surface runoff that will remove 90% of stored fecal coliform per hour (WSQOP). All of these parameters were initially set at expected levels for the watershed conditions and adjusted within reasonable limits until an acceptable match between measured and modeled fecal coliform concentrations was established (Table 4.14). Figures 4.16 through 4.21 show the results of calibration. During the water quality calibration and validation periods, the input concentration for incoming flow in the James River was based on observed concentrations at VADEQ Station 2-JMS176.63. This was necessary since the portion of the James River basin upstream of the current study area was not directly modeled in the current TMDL project. For the sake of illustrating the impact of this approach, the observed concentrations from VADEQ Station 2-JMS176.63 were plotted along with the observed fecal coliform concentrations from the calibration station (VADEQ Station 2-JMS157.28) on the upper James River impairment. As can be seen from Figure 4.21, there is not always an agreement between concentrations observed at the two stations. This can be attributed to the fact that samples were not collected on the same day at both stations and taking grab samples from two stations that are approximately 19 stream miles apart does not represent the daily variability that we would expect for bacteria.

Table 4.14 Model parameters utilized for water quality calibration.

Parameter	Units	Typical Range of Parameter Value	Initial Parameter Estimate	Calibrated Parameter Value
MON-SQOLIM	FC/ac	1.0E-02 – 1.0E+30	8E+6 to 1E+11	9E+6 to 3.9E+12
WSQOP	in/hr	0.05 – 3.00	1	0.14 – 2.8
FSTDEC	1/day	0.01 – 10.00	1	0.01 to 1.9

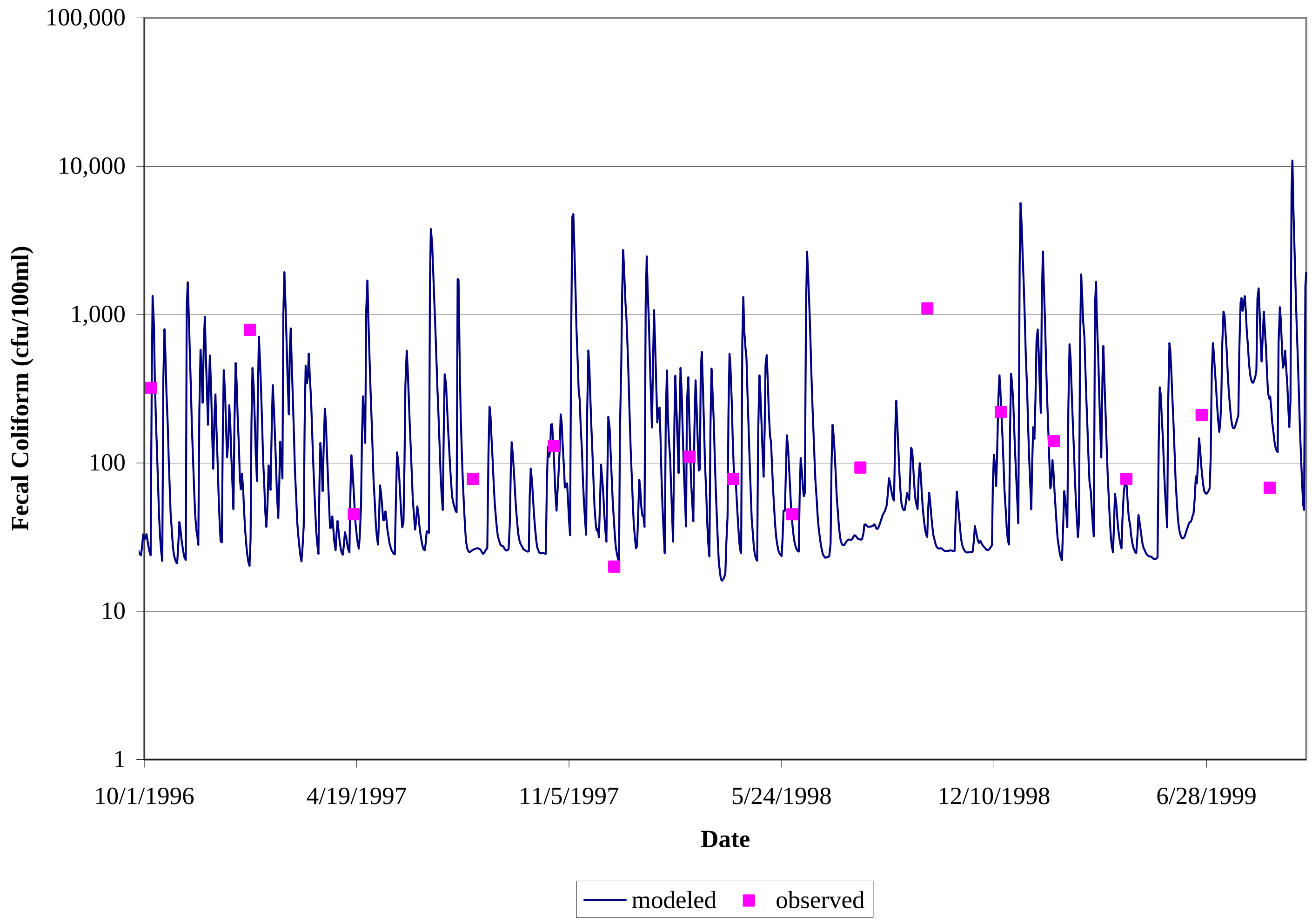

Figure 4.16 Quality calibration results for 10/1/1996 to 9/30/1999 for Byrd Creek, subwatershed 11 (VADEQ Station 2-BYR003.35).

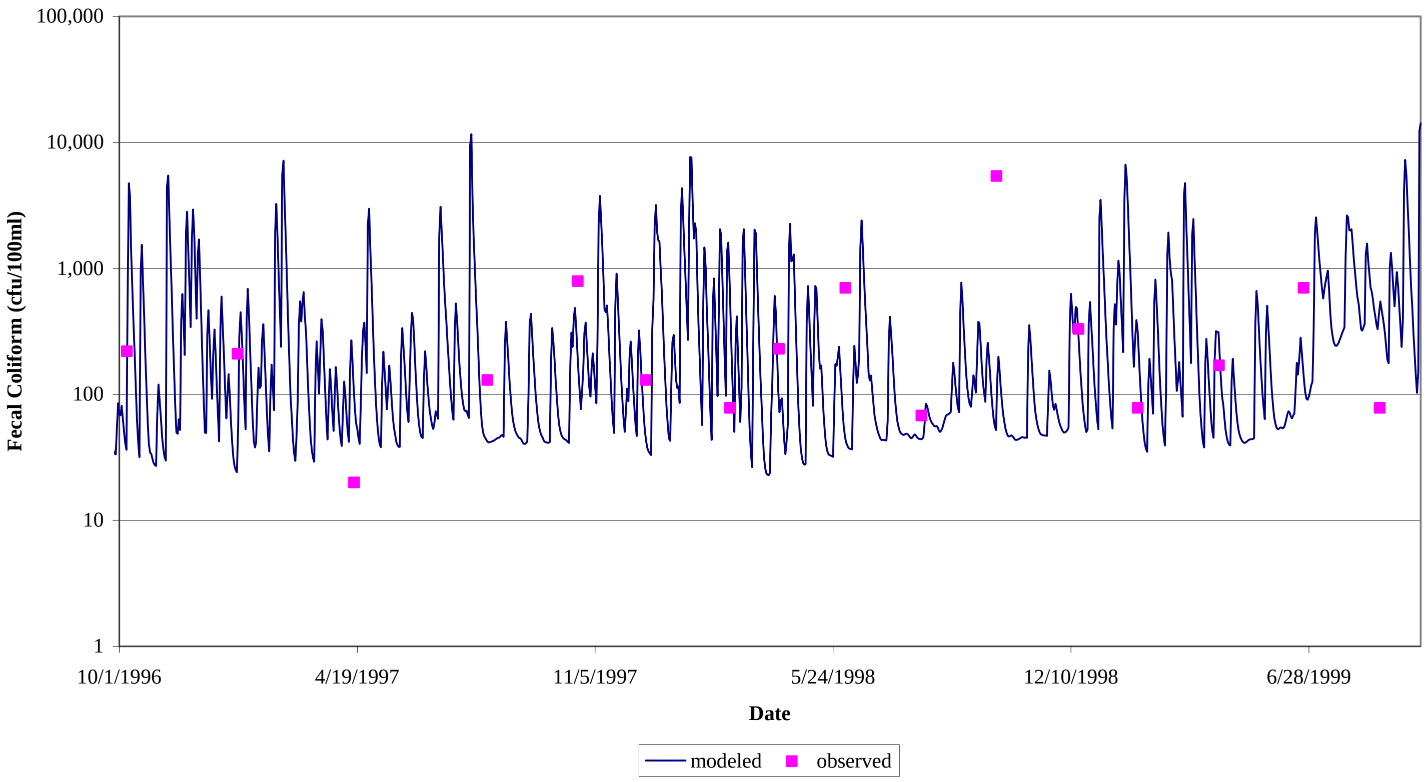

Figure 4.17 Quality calibration results for 10/1/1996 to 9/30/1999 for Beaverdam Creek, subwatershed 18 (VADEQ Station2-BDC000.79).

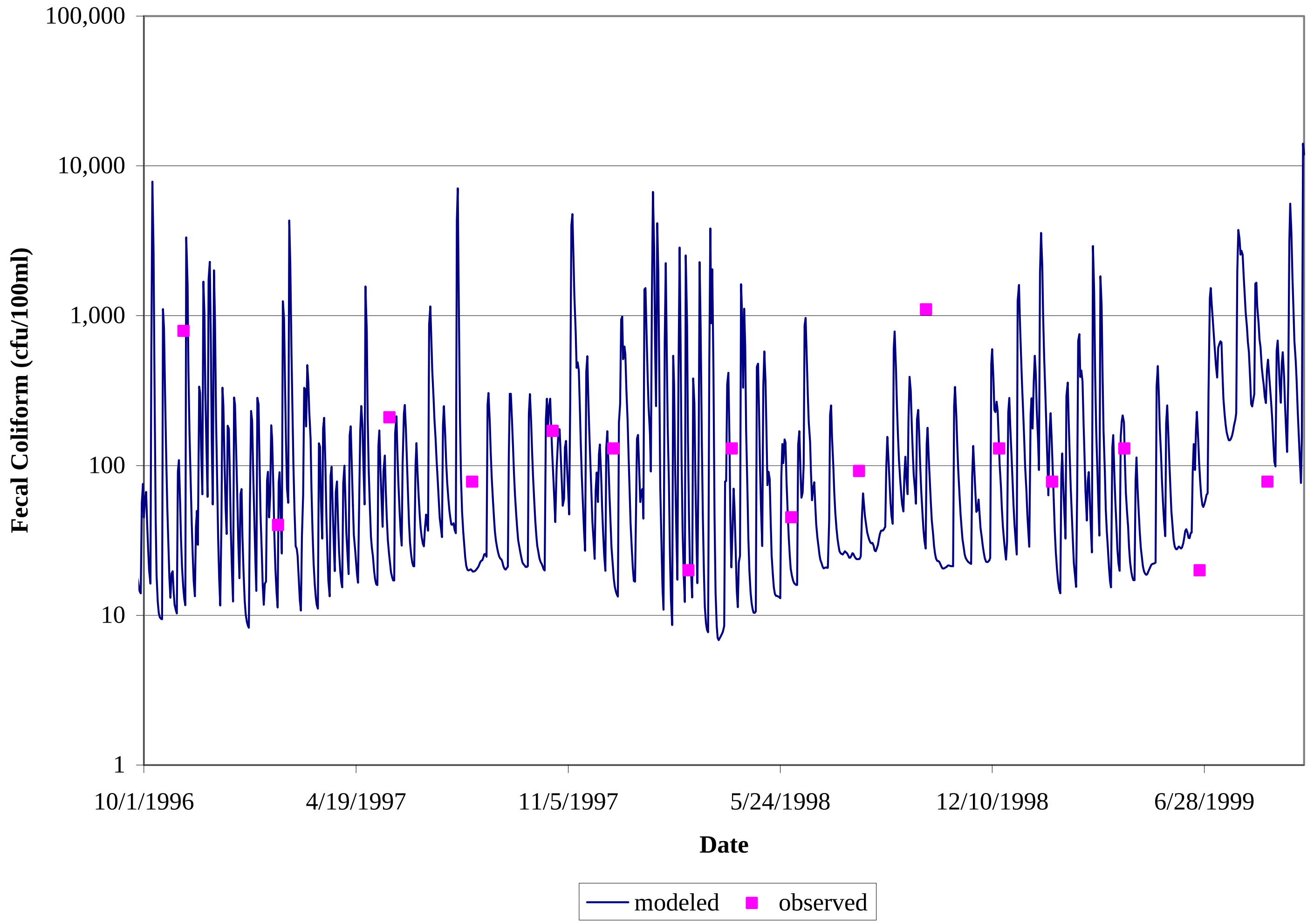

Figure 4.18 Quality calibration results for 10/1/1996 to 9/30/1999 for Fine Creek, subwatershed 19 (VADEQ Station 2-FIN000.81).

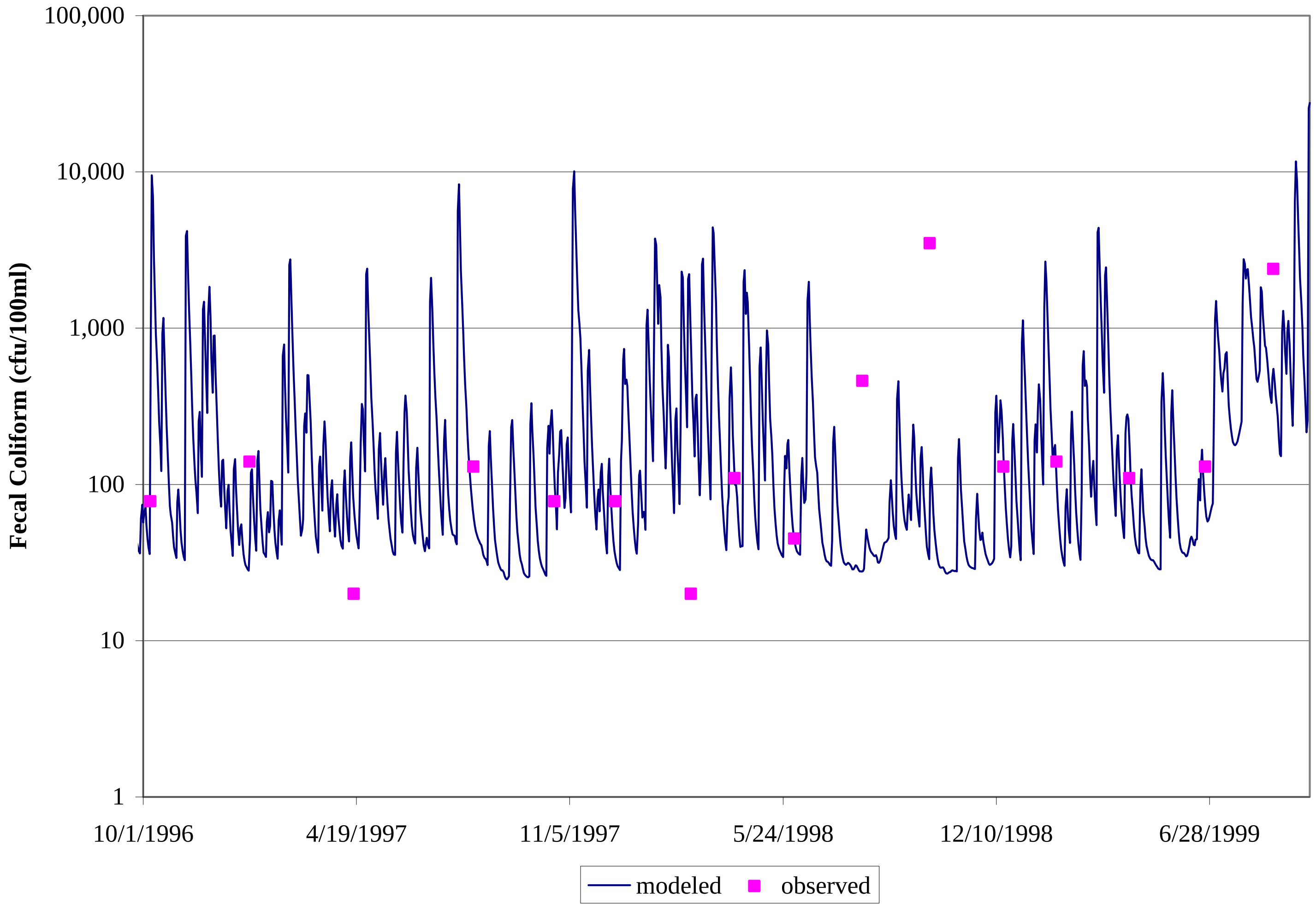

Figure 4.19 Quality calibration results for 10/1/1996 to 9/30/1999 for Big Lickinghole Creek, below the confluence of subwatershed 14 and subwatershed 16 (VADEQ Station 2-BLG002.60).

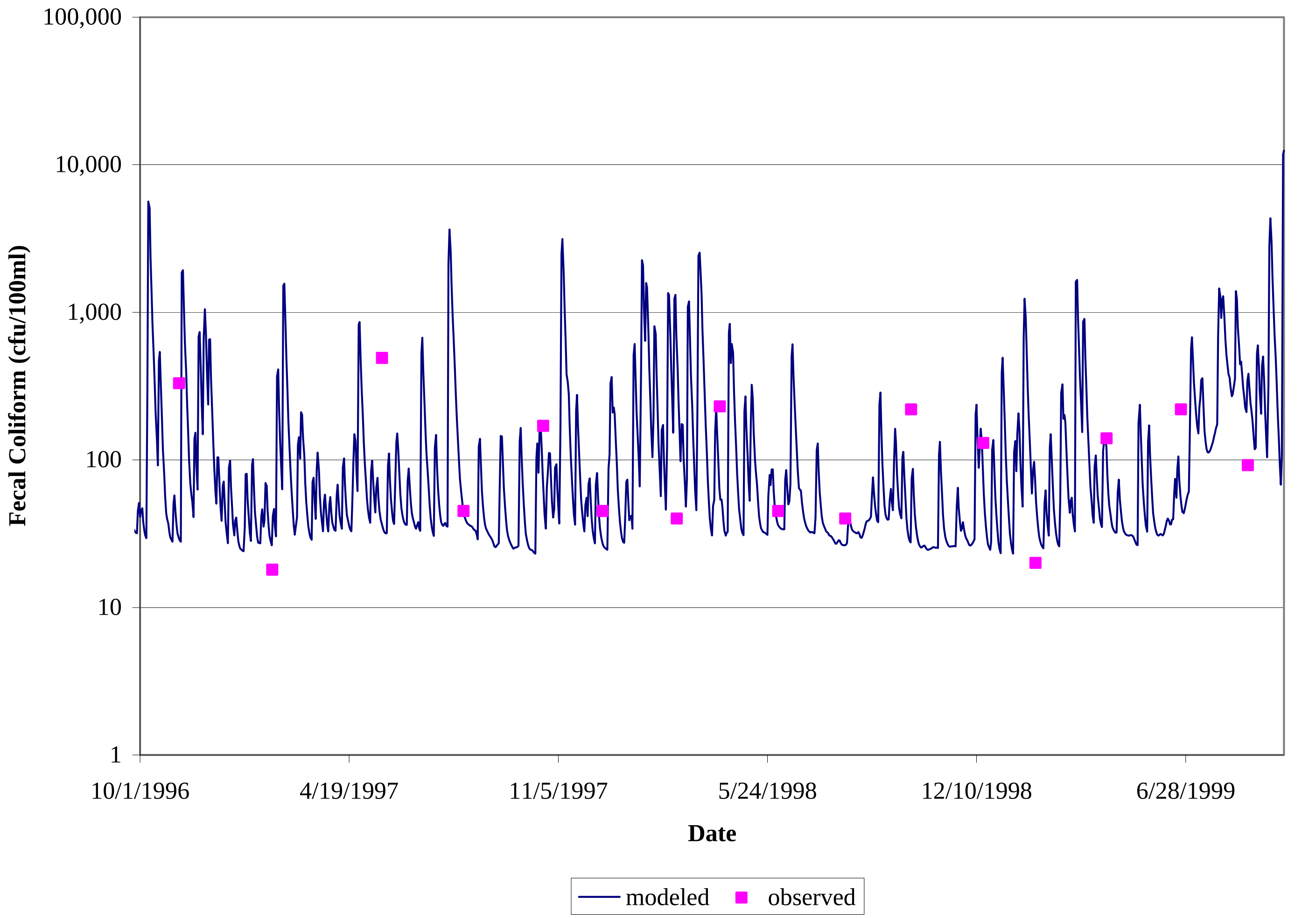

Figure 4.20 Quality calibration results for 10/1/1996 to 9/30/1999 for Deep Creek, below the confluence of subwatershed 32 and subshed 33 (VADEQ Station 2-DCR003.00).

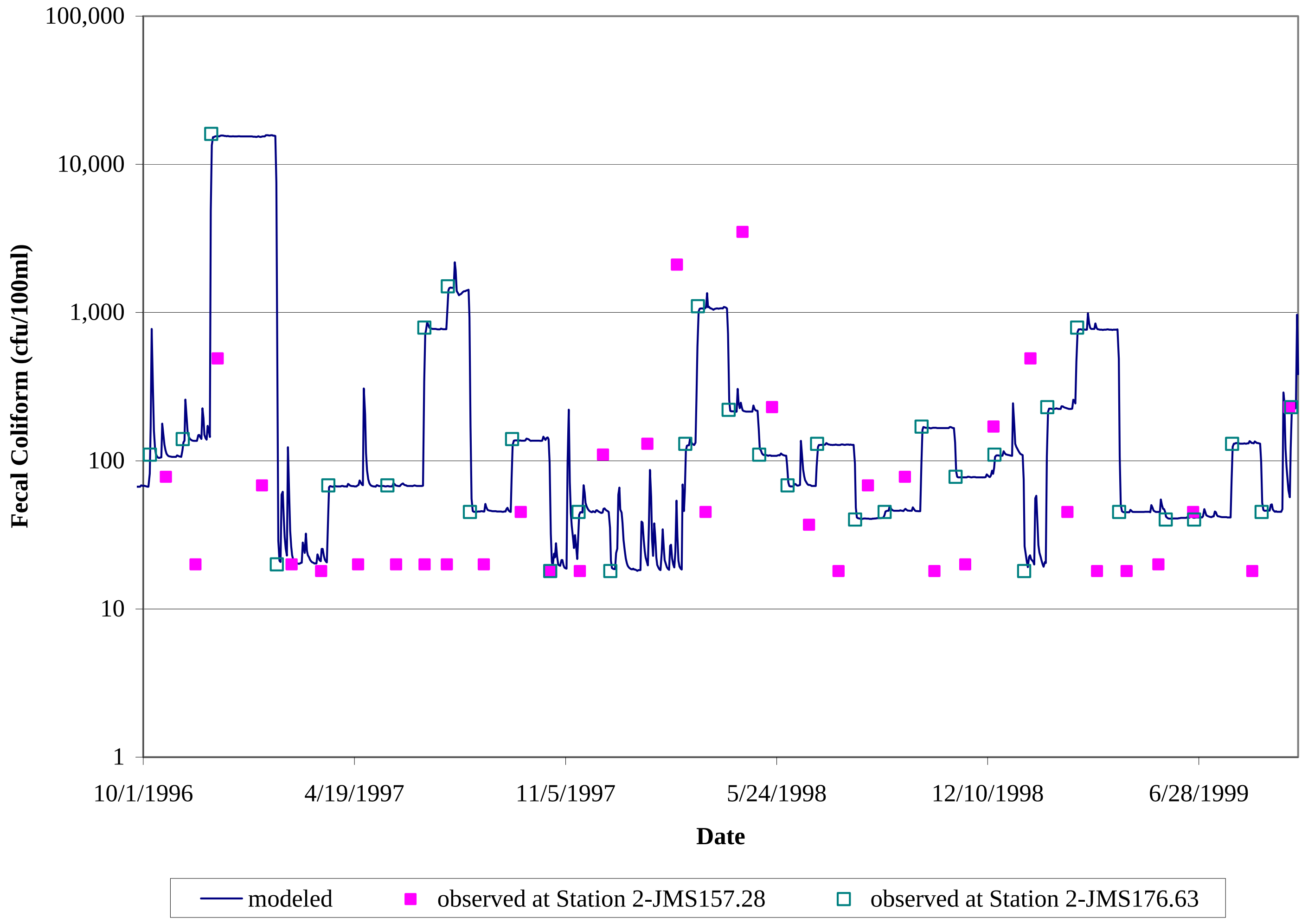

Figure 4.21 Quality calibration results for 10/1/1996 to 9/30/1999 for James River, subwatershed 2 (VADEQ Station 2JMS157.28).

Careful inspection of graphical comparisons between continuous simulation results and limited observed points was the primary tool used to guide the calibration process. To provide a quantitative measure of the agreement between modeled and measured data while taking the inherent variability of fecal coliform concentrations into account, each observed value was compared with modeled concentrations in a 2-day window surrounding the observed data point. Standard error in each observation window was calculated as follows:

$$Standard\ Error = \frac{\sqrt{\dfrac{\sum_{i=1}^{n}\left(observed - modeled_i\right)^2}{(n-1)}}}{\sqrt{n}}$$

where

$observed$ = an observed value of fecal coliform
$modeled_i$ = a modeled value in the 2-day window surrounding the observation
n = the number of modeled observations in the 2-day window

This is a non-traditional use of standard error, applied here to offer a quantitative measure of model accuracy. In this context, standard error measures the variability of the sample mean of the modeled values about an instantaneous observed value. The use of limited instantaneous observed values to evaluate continuous data introduces error and, therefore, increases standard error. The mean of all standard errors for each station analyzed was calculated. Additionally, the maximum concentration values observed in the simulated data were compared with maximum values obtained from uncensored data (Chapter 2) and found to be at reasonable levels (Table 4.15). The standard errors in Table 4.15 range from a low of 15 to a high of 78, with the majority of standard errors below 50. Thus, the standard errors calculated for these impairments are considered an indicator of strong model performance.

Table 4.15 Results of analyses on calibration runs.

WQ Monitoring Station	Mean Standard Error (cfu/100ml)	Maximum Simulated Value (cfu/100ml)
2-BYR003.35	27	10,922
2-BDC000.79	78	14,110
2-FIN000.81	27	14,111
2BLG002.60	46	27,638
2DCR003.00	15	12,501
2JMS157.28	54	15,720

Table 4.16 shows the predicted and observed values for instantaneous standard violation rate and the geometric mean for all impaired stream segments in the James River and Tributaries – Lower Piedmont Region. For the majority of stations with a substantial sample population, differences between both the violation rates and geometric means are well within the range of reasonable model error.

The water quality validation was conducted for the time period from 10/01/1999 to 9/30/2001. The relationship between observed values and modeled values are shown in in Appendix D.

Table 4.16 Comparison of modeled and observed geometric means and exceedance of instantaneous standard for all monitoring stations used in the analysis.

			Modeled Calibration Load Fecal Coliform 10/1/96 - 9/30/99			Monitored Fecal Coliform 10/1/96-9/30/99		
Impairment	**Reach ID**	**Station ID**	***n*[1]**	**Geometric Mean (cfu/100ml)**	**Exceedances of Instantaneous Standard**	***n*[1]**	**Geometric Mean (cfu/100ml)**	**Exceedances of Instantaneous Standard**
Byrd Creek	11	2-BYR003.35	1095	94.73	15.16%	16	124.00	12.50%
Beaverdam Creek	18	2-BDC000.79	1095	166.88	22.56%	16	209.33	25.00%
Fine Creek	19	2-FIN000.81	1095	81.84	13.79%	16	106.61	12.50%
Big & Little Lickinghole Creek	Below confluence of 14 & 16	2BLG002.60	1095	133.54	20.18%	16	137.95	18.75%
Deep Creek (not impaired)	Below confluence of 32 & 33	2DCR003.00	1095	82.83	11.23%	16	92.12	6.25%
James River, H33R-01	2	2JMS157.28	1095	121.60	16.35%	35	54.37	11.43%

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5. ALLOCATION

Total Maximum Daily Loads (TMDLs) consist of waste load allocations (WLAs, permitted sources) and load allocations (LAs, nonpoint sources) including natural background levels. Additionally, the TMDL must include a margin of safety (MOS) that either implicitly or explicitly accounts for the uncertainties in the process (*e.g.*, accuracy of wildlife populations). The definition is typically denoted by the expression:

TMDL = WLAs + LAs + MOS

The TMDL becomes the amount of a pollutant that can be assimilated by the receiving waterbody and still achieve water quality standards. For fecal coliform bacteria, the TMDL is expressed in terms of colony forming units (or resulting concentration). A sensitivity analysis was performed to determine the impact of uncertainties in input parameters.

5.1 Incorporation of a Margin of Safety

In order to account for uncertainty in modeled output, a MOS was incorporated into the TMDL development process. Individual errors in model inputs, such as data used for developing model parameters or data used for calibration, may affect the load allocations in a positive or a negative way. A margin of safety can be incorporated implicitly in the model through the use of conservative estimates of model parameters, or explicitly as an additional load reduction requirement. The intention of an MOS in the development of a fecal coliform TMDL is to ensure that the modeled loads do not underestimate the actual loadings that exist in the watershed. An implicit MOS was used in the development of this TMDL. By adopting an implicit MOS in estimating the loads in the watershed, it is ensured that the recommended reductions will in fact succeed in meeting the water quality standard. Examples of the implicit MOS used in the development of this TMDL are:

- Allocating permitted point sources at the maximum allowable fecal coliform concentration, and
- Selecting a modeling period that represented the critical hydrologic conditions in the watershed.

5.2 Scenario Development

Allocation scenarios were modeled using HSPF. Using bacteria loads representing existing conditions as model inputs, reductions were applied to those loads until the water quality standards were attained. The TMDLs developed for the James River Tributaries – Lower Piedmont Region were based on the Virginia State Standard for *E. coli*. As detailed in Section 2.1, the *E. coli* standards state that the calendar month geometric-mean concentration shall not exceed 126 cfu/100 ml, and that a maximum single sample concentration of *E. coli* shall not exceed 235 cfu/100 ml. According to the guidelines put forth by the VADEQ (VADEQ, 2003) for modeling *E. coli* with HSPF, the model was set up to estimate loads of fecal coliform, then the model output was converted to concentrations of *E. coli* through the use of the following equation (developed from a data set containing 493 paired data points):

$$\log_2(C_{ec}) = -0.0172 + 0.91905 \cdot \log_2(C_{fc})$$

where C_{ec} is the concentration of *E. coli* in cfu/100 ml, and C_{fc} is the concentration of fecal coliform in cfu/100 ml.

Pollutant concentrations were modeled over the entire duration of a representative modeling period and pollutant loads were adjusted until the standard was met (Figures 5.1 through 5.6). The development of the allocation scenario was an iterative process that required numerous runs with each followed by an assessment of source reduction against the water quality target.

5.2.1 Waste Load Allocations

There are eighteen point sources currently permitted to discharge into the James River Tributaries – Lower Piedmont Region (Figure 3.2 and Table 3.2). The allocation for the sources permitted for *E. coli* control is equivalent to their current permit levels (design discharge and 126 cfu/100 ml). Future growth in each watershed was accounted for by assuming a 500% growth in permitted discharges. For watersheds with no existing point sources such as Fine Creek and Big and Little Lickinghole Creeks, future growth was accounted for as a 1% of the current TMDL in the watershed.

5.2.2 Load Allocations

Load allocations to nonpoint sources are divided into land-based loadings from land uses and directly applied loads in the stream (*e.g.,* livestock, sewer overflows, and wildlife). Source reductions include those that are affected by both high and low flow conditions. Land-based NPS loads had their most significant impact during high-flow conditions, while direct deposition NPS had their most significant impact on low flow concentrations. The BST results for 2005-2006 confirmed the presence of human, livestock, pet, and wildlife contamination. Load reductions were performed by land use, as opposed to reducing sources, as it is considered that the majority of BMPs will be implemented by land use.

Allocation scenarios were run sequentially, beginning with headwater impairments, and then continuing with downstream impairments until all impairments were allocated to 0% exceedances of the standards. Tables 5.1 through 5.6 represent a portion of the scenarios developed to determine the TMDL for each impairment. Scenario 1 in each table describes a baseline scenario that corresponds to the existing conditions in the watershed. Model results indicate that human, livestock, and wildlife contributions are significant in all areas of the watershed. This is in agreement with the results of BST analysis presented in Section 2.4.2.1.

The second scenario in the scenario tables (Tables 5.1 through 5.6) shows the reduction in percentage violation of both standards when direct human loads are eliminated. Those loads are illegal and are usually the first to be addressed during implementation of the TMDL. Scenario 3 in all the tables looks at the combined effect of eliminating direct bacteria contributions from both illicit human sources and livestock in streams.

Scenarios exploring the role of anthropogenic sources in standards violations were then explored to determine the feasibility of meeting standards without wildlife reductions. In each table, scenario 4 attempts to determine the impact of non-anthropogenic sources (*i.e.,* wildlife), by exploring 100% reductions in all anthropogenic land-based and direct loads. Except for the case of the James River impairments, the model predicts that water quality standards will not be met without reductions in wildlife loads.

Since part of the TMDL development is the identification of phased implementation strategies, typical management scenarios were explored as well. Scenario 5 in each table contains reductions of 50% in all anthropogenic land-based loads, 100% reduction in uncontrolled residential discharges, a 90% reduction in direct livestock deposition, and a 0% reduction in wildlife direct and land-based loading to the stream. This scenario corresponds to what is considered to be a reasonable scenario for a Stage I implementation. Further scenarios in each table explore a range of management scenarios, leading to the final allocation scenario that contains the predicted reductions needed to meet the water quality standard of 0% instantaneous and geometric mean violations. Multiple scenarios are also listed in most tables that give different options for meeting the Stage I implementation goal of 10.5% violation rate of the instantaneous standard.

5.2.2.1 Byrd Creek Impairment

Byrd Creek drains the eastern part of Fluvanna County and the western part Goochland County. The impaired section begins at the headwaters continues downstream to the confluence with Little River (25.97 stream miles). The watershed is 77% forest with 16% pasture. Byrd Creek flows into the upper impairment of the James River (top of subwatershed 2).

The total fecal coliform production per year in the watershed was modeled as 2.68E+15. Major sources of fecal coliform bacteria are dairy cows (30%), beef cattle (31%) and horses (9%). The total wildlife contribution to the fecal coliform load is about 16%. The VADEQ monitoring stations, 2-BYR003.35, has historical fecal coliform violations rate of 23%.

In addition to the scenarios discussed in Section 5.2.2, scenarios 6 through 11 explore various combinations of reductions to land-based and direct loads to achieve an approximate 10.5% violation of the instantaneous standard. This violation rate is the target for the Stage I of an implementation plan. Scenario 13 shows the final allocation scenario for Byrd Creek, which requires 100% reductions in all anthropogenic direct sources, 99% reductions in non-point pasture / livestock access / cropland loads, 99% reductions in residential and urban land-based loads. A 71% reduction is necessary in wildlife land-based loads and direct loads in order to obtain no violations of the standards.

Table 5.1 Allocation scenarios for bacterial concentration with current loading estimates in subwatershed 10, Byrd Creek.

Scenario Number	Percent Reduction in Loading from Existing Condition						Percent Violations	
	Direct Wildlife Loads	NPS Forest/ Wetlands	Direct Livestock Loads	NPS Agricultural Land	NPS Residential/ Commercial Land	Direct Human Loads	Geometric Mean > 126 cfu/100ml	Single Sample > 235 cfu/100ml
1	0	0	0	0	0	0	36.11	26.94
2	0	0	0	0	0	100	30.56	26.12
3	0	0	100	0	0	100	22.22	25.21
4	0	0	100	100	100	100	0	1.64
5	0	0	90	50	50	100	8.33	18.63
6	0	0	99	75	75	100	0	11.23
7	0	0	99	78.2	78.2	100	0	10.41
8	0	0	90	75	50	100	5.56	10.32
9	0	0	80	80	80	100	5.56	9.95
10	0	0	0	0	95	100	5.56	8.86
11	0	0	0	0	91	100	5.56	10.32
12	50	50	100	99	99	100	0	0.37
13	71	71	100	99	99	100	0	0

5.2.2.2 Big & Little Lickinghole Creeks

Big & Little Lickinghole Creeks drain the central part of Goochalnd County. The impaired section begins at the headwaters of both creeks and continues downstream to the confluence with the James River (29.54 stream miles). The watershed is 76% forest with 14% pasture. Big & Little Lickinghole Creeks flow into the James River, downstream of the upper James River impairment and upstream of the lower James River impairment (top of subwatershed 5).

The total fecal coliform production per year in the watershed was modeled as 4.08E+15. Major sources of fecal coliform bacteria are poultry (55%), beef cattle (14%), and horses (12%). The total wildlife contribution to the fecal coliform load is about 15%. The

VADEQ monitoring stations, 2-BLG002.60, has historical fecal coliform violations rate of 24%.

In addition to the scenarios discussed in Section 5.2.2, scenarios 6 through 11 explore various combinations of reductions to land-based and direct loads to achieve an approximate 10.5% violation of the instantaneous standard. This violation rate is the target for Stage I of the implementation plan. Scenario 13 shows the final allocation scenario for Big & Little Lickinghole Creeks, which requires 100% reductions in all anthropogenic direct sources, 99% reductions in non-point pasture / livestock access / cropland loads, 99% reductions in residential and urban land-based loads. A 53.5% reduction is necessary in wildlife land-based loads and direct loads in order to obtain no violations of the standards.

Table 5.2 Allocation scenarios for bacterial concentration with current loading estimates in subwatershed 16, Big & Little Lickinghole Creeks.

Scenario Number	Percent Reduction in Loading from Existing Condition						Percent Violations	
	Direct Wildlife Loads	NPS Forest/ Wetlands	Direct Livestock Loads	NPS Agricultural Land	NPS Residential/ Commercial Land	Direct Human Loads	Geometric Mean > 126 cfu/100ml	Single Sample > 235 cfu/100ml
1	0	0	0	0	0	0	33.33	23.56
2	0	0	0	0	0	100	22.22	23.2
3	0	0	100	0	0	100	19.44	22.65
4	0	0	100	100	100	100	0	0.64
5	0	0	90	50	50	100	8.33	13.88
6	0	0	99	65	65	100	5.56	10.59
7	0	0	99	66	66	100	2.78	10.41
8	0	0	68	68	68	100	2.78	9.86
9	0	0	67	67	67	100	5.56	10.32
10	0	0	0	75	0	100	5.56	10.9
11	0	0	0	77	0	100	5.56	10.23
12	0	0	100	99	99	100	0	1
13	53.5	53.5	100	99	99	100	0	0

5.2.2.3 Beaverdam Creek Impairment

Beaverdam Creek is located in the central part of Goochland County. The impaired section begins at the headwaters continues downstream to the confluence with the James River (8.73 stream miles). The watershed is 66% forest with 21% pasture.

The total fecal coliform production per year in the watershed was modeled as 2.66E+15. Major sources of fecal coliform bacteria are dairy cows (29%), beef cattle (28%) and horses (14%). The total wildlife contribution to the fecal coliform load is about 16%. The VADEQ monitoring stations, 2-BDC000.79, has historical fecal coliform violations rate of 17%. Beaverdam Creek flows into the James River downstream of both James River impairments and therefore, does not impact either one of those two impairments.

In addition to the scenarios discussed in Section 5.2.2, scenarios 6 through 11 explore various combinations of reductions to land-based and direct loads to achieve an approximate 10.5% violation of the instantaneous standard. This violation rate is the target for the Stage I of an implementation plan. Scenario 13 shows the final allocation scenario for Beaverdam Creek, which requires 100% reductions in all anthropogenic direct sources, 99% reductions in non-point pasture / livestock access / cropland loads, 99% reductions in residential and urban land-based loads. A 77% reduction is necessary in wildlife land-based loads and direct loads in order to obtain no violations of the standards.

Table 5.3 Allocation scenarios for bacterial concentration with current loading estimates in subwatershed 18, Beaverdam Creek.

Scenario Number	Percent Reduction in Loading from Existing Condition						Percent Violations	
	Direct Wildlife Loads	NPS Forest/ Wetlands	Direct Livestock Loads	NPS Agricultural Land	NPS Residential/ Commercial Land	Direct Human Loads	Geometric Mean > 126 cfu/100ml	Single Sample > 235 cfu/100ml
1	0	0	0	0	0	0	61.11	32.6
2	0	0	0	0	0	100	44.44	30.78
3	0	0	100	0	0	100	33.33	30.14
4	0	0	100	100	100	100	0	1.55
5	0	0	90	50	50	100	8.33	20.46
6	0	0	99	90	90	100	0	6.3
7	0	0	99	78	78	100	0	10.32
8	0	0	79	79	79	100	0	10.23
9	0	0	70	70	99	100	0	10.59
10	0	0	71	71	99	100	0	10.59
11	0	0	73	73	99	100	0	10.23
12	76	76	100	99	99	100	0	0.09
13	77	77	100	99	99	100	0	0

5.2.2.4 Fine Creek Impairment

Fine Creek is the only impairment within the current study area that is completely located within Powhatan County. Fine Creek flows southwest to northeast and ends at the James River. The impaired section begins at the headwaters and continues downstream to the confluence with the James River (10.34 stream miles). The watershed is 67% forest with 19% pasture.

The total fecal coliform production per year in the watershed was modeled as 1.04E+15. Major sources of fecal coliform bacteria are beef cattle (36%), horses (27%), and deer (20%). The remaining wildlife contribution to the fecal coliform load is about 12%. The VADEQ monitoring station, 2-FIN000.81, has a historical fecal coliform violation rate of 16%.

In addition to the scenarios discussed in Section 5.2.2, scenarios 6 through 13 explore various combinations of reductions to land-based and direct loads to achieve the approximate 10.5% violation of the instantaneous standard. This violation rate is the target for the Stage I of the implementation plan. Scenario 16 shows the final allocation scenario for Fine Creek, which requires 100% reductions in all anthropogenic direct sources, 99% reductions in non-point pasture / livestock access / cropland loads, 99% reductions in residential and urban land-based loads. A 53% reduction is necessary in wildlife land-based loads and direct loads in order to obtain no violations of the standards.

Table 5.4 Allocation scenarios for bacterial concentration with current loading estimates in subwatershed 19, Fine Creek.

Scenario Number	Percent Reduction in Loading from Existing Condition						Percent Violations	
	Direct Wildlife Loads	**NPS Forest/ Wetlands**	**Direct Livestock Loads**	**NPS Agricultural Land**	**NPS Residential/Commercial Land**	**Direct Human Loads**	**Geometric Mean > 126 cfu/100ml**	**Single Sample > 235 cfu/100ml**
1	0	0	0	0	0	0	5.56	11.6
2	0	0	0	0	0	100	5.56	11.23
3	0	0	100	0	0	100	5.56	10.78
4	0	0	100	100	100	100	0	0.37
5	0	0	90	50	50	100	0	5.21
6	0	0	40	40	40	100	5.56	6.67
7	0	0	11	11	11	100	5.56	10.14
8	0	0	99	12	12	100	5.56	9.86
9	0	0	99	8	8	100	5.56	10.41
10	0	0	0	30	0	100	0	9.68
11	0	0	0	15	0	100	5.56	10.32
12	0	0	0	0	20	100	5.56	10.05
13	0	0	0	0	15	100	5.56	10.23
14	20	20	100	99	99	100	0	0.37
15	55	55	100	99	99	100	0	0
16	53	53	100	99	99	100	0	0

5.2.2.5 Upper James River impairment, H33R-01

Within the current study area, the James River flows in between Fluvanna and Cumberland counties and then continues between Goochland and Powhatan counties and has two impaired segments before it continues downstream towards Richmond. The upper impaired segment starts at the point on the River where Fluvanna County meets Cumberland County and spans over approximately 60% of the length of the river (22.87 miles) within the current study area. This impaired segment of the James River is impacted by Byrd Creek. Aside from the contributing area of Byrd Creek, the watershed is 75% forest with 16% pasture. Those statistics are reflective of subwatersheds 1, 2, 3, 4, 31, 32, 33, and 34.

The total fecal coliform production per year in the watershed was modeled as 1.27E+16. Major sources of fecal coliform bacteria are poultry (32%), dairy cows (23%), beef cattle (17%), and horses (7%). The total wildlife contribution to the fecal coliform load is about 10%. The VADEQ monitoring stations, 2-JMS157.28, has historical fecal coliform violations rate of 10%.

The upper James River impairment receives flow from the upland drainage area of the James River that is not modeled directly in the current TMDL project. During the allocation phase, the incoming flow was assumed to have a fecal coliform concentration equal to the geometric mean standard (200 cfu/100 ml). Under this assumption, and considering the die-off rate within the modeled segment of the James River, the result was that no action was needed on part of local stakeholders to meet the violation rate goal of 10.5% for the instantaneous standard (scenario 1(a)). However, to give local stakeholders and concerned agencies an insight into how different the situation might be if the incoming concentration was left at existing conditions, another scenario (scenario 1(b)) was generated where the incoming concentration of bacteria in the James River was left at the observed levels during the allocation phase of the study. This scenario resulted in the instantaneous *E*.coli standard being violated 14.69% of the time. The higher percentage violation of the geometric mean standard for scenarios 1(a) and 1(b) can be explained if one considers the way the incoming flow from the upstream drainage area of the James River was incorporated into the model. As explained in Section 4.7.3 and illustrated in Figure 4.21, the concentration in the monthly bacteria samples observed in the incoming flow of the James River were assumed to be constant until another monthly sample was observed. Therefore, if one sample has a concentration of bacteria higher than the geometric mean, that resulted in about 30 days of violation of the geometric mean.

In addition to the scenarios discussed in Section 5.2.2, scenarios 6 through 10 explore various combinations of reductions to land-based and direct loads to achieve a zero percent violation rate of both standards. Those five scenarios (scenarios 6 though 10) were run with the upstream impairments allocated to both standards. Different options were evaluated in those scenarios such as equal reductions from various sources (scenarios 9 and 10). It can be seen by reviewing Table 5.5 that scenarios 7 and 9 resulted in the same percentage violation of the instantaneous and geometric mean standards even though scenario 9 required 89% reductions from direct deposition of livestock as well as nonpoint source bacterial contributions from residential and commercial areas. This result is not unusual considering that land based livestock contributions in the impacted subs are by far a majority of the sources and that direct livestock deposition has more impact on geometric mean than on instantaneous standard violations. Scenario 10 shows the final allocation scenario for the upper James River segment, which requires 90% reductions in all anthropogenic direct sources, 90% reductions in non-point pasture / livestock access / cropland loads, and 90% reductions in residential and urban land-based loads. No reductions in wildlife land-based loads and direct loads were necessary in order to obtain zero violations of the standards.

Table 5.5 Allocation scenarios for bacterial concentration with current loading estimates in subwatershed 4, James River, H33R-01.

Scenario Number	Percent Reduction in Loading from Existing Condition						Percent Violations	
	Direct Wildlife Loads	NPS Forest/ Wetlands	Direct Livestock Loads	NPS Agricultural Land	NPS Residential/ Commercial Land	Direct Human Loads	Geometric Mean > 126 cfu/100ml	Single Sample > 235 cfu/100ml
1(a)	0	0	0	0	0	0	33.33	3.29
1(b)	0	0	0	0	0	0	27.78	14.61
2	0	0	0	0	0	100	30.56	3.29
3	0	0	100	0	0	100	27.78	3.29
4	0	0	100	100	100	100	0	0
5	0	0	90	50	50	100	13.89	1.74
6	0	0	100	0	0	100	19.44	2.56
7	0	0	0	89	0	100	0	0.18
8	0	0	0	91	0	100	0	0
9	0	0	89	89	89	100	0	0.18
10	0	0	90	90	90	100	0	0

5.2.2.6 Lower James River impairment, H38R-04

The lower impaired segment of the James River receives flow from Big and Little Lickinghole Creeks, the upper impaired segment of the James River, and in turn, from Byrd Creek. The lower James River impairment extends from the confluence of Mohawk Creek downstream to river mile 137 (3.64 river miles). Aside from the contributing area of the upstream impairments, the watershed is 73% forest with 17% pasture. Those statistics are reflective of subwatershed 5.

The total fecal coliform production per year in the watershed was modeled as 2.68E+15. Major sources of fecal coliform bacteria are dairy cows (24%), beef cattle (24%), poultry (19%), and horses (15%). The total wildlife contribution to the fecal coliform load is about 9%. The VADEQ monitoring station, 2-JMS140.00, has a historical fecal coliform violation rate of 11%.

Due to flow incoming from an upstream area that is not modeled within the current TMDL project, similar scenarios were run as those for the upper James River impairment. During the allocation phase, the incoming flow was assumed to have fecal coliform concentration equal to the geometric mean standard (200 cfu/100 ml). Under this assumption, and considering the die-off rate within the modeled segment of the James River, the result was that no action was needed on the part of local stakeholders to meet the violation rate goal of 10.5% for the instantaneous standard (scenario 1(a)). However, to give local stakeholders and concerned agencies an insight into how different the situation might be if the incoming concentration was left at existing conditions, another scenario (scenario 1(b)) was generated where the incoming concentration of bacteria in the James River was left at the observed levels during the allocation phase of the study. This scenario resulted in the instantaneous *E.*coli standard being violated 15.16% of the time.

In addition to the scenarios discussed in Section 5.2.2, scenarios 6 through 11 explore various combinations of reductions to land-based and direct loads to achieve a zero percent violation rate of both standards. Those six scenarios (scenarios 6 through 11) were run with the upstream impairments allocated to both standards. Scenario 9 shows the final allocation scenario for the upper James River segment, which requires 93% reductions in all anthropogenic direct sources, 93% reductions in non-point pasture / livestock access / cropland loads, and 93% reductions in residential and urban land-based loads. No reductions in wildlife land-based loads and direct loads were necessary in order to obtain no violations of the standards.

Table 5.6 Allocation scenarios for bacterial concentration with current loading estimates in subwatershed 5, James River, H38R-04.

Scenario Number	Percent Reduction in Loading from Existing Condition						Percent Violations	
	Direct Wildlife Loads	NPS Forest/ Wetlands	Direct Livestock Loads	NPS Agricultural Land	NPS Residential/ Commercial Land	Direct Human Loads	Geometric Mean > 126 cfu/100ml	Single Sample > 235 cfu/100ml
1(a)	0	0	0	0	0	0	38.89	3.93
1(b)	0	0	0	0	0	0	27.78	15.16
2	0	0	0	0	0	100	30.56	3.93
3	0	0	100	0	0	100	27.28	3.93
4	0	0	100	100	100	100	0	0
5	0	0	90	50	50	100	13.89	2.01
6	0	0	100	0	0	100	19.44	3.38
7*	0	0	0	89	0	100	0	0.18
8	0	0	92	92	92	100	0	0.09
9	0	0	93	93	93	100	0	0
10	0	0	0	94	0	100	0	0
11	0	0	0	93	0	100	0	0.09

* Scenarios 7 through 11 were obtained with contributing bacteria concentration from Byrd Creek and Big & Little Lickinghole Creeks fully allocated while scenarios 1 through 6 were run with Byrd Creek and Big & Little Lickinghole Creeks contributions at existing conditions.

Figures 5.1 through 5.6 show the daily instantaneous values for existing and allocated conditions for all impairments in the James River and Tributaries – Lower Piedmont Region. These graphs show allocated conditions in black, overlaid with existing conditions in gray

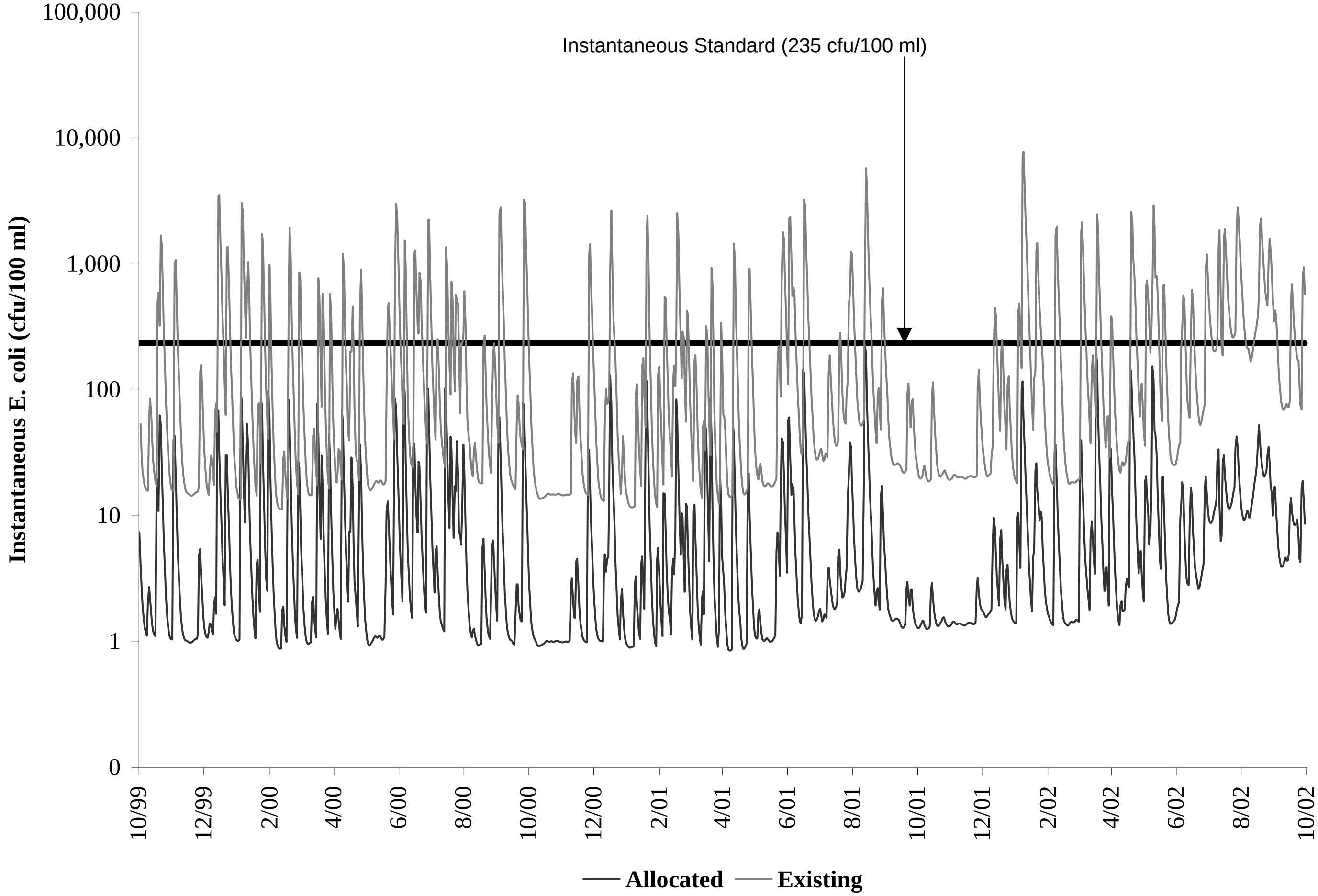

Figure 5.1 Existing and allocation scenarios of *E. coli* concentrations in subwatershed 10, Byrd Creek impairment.

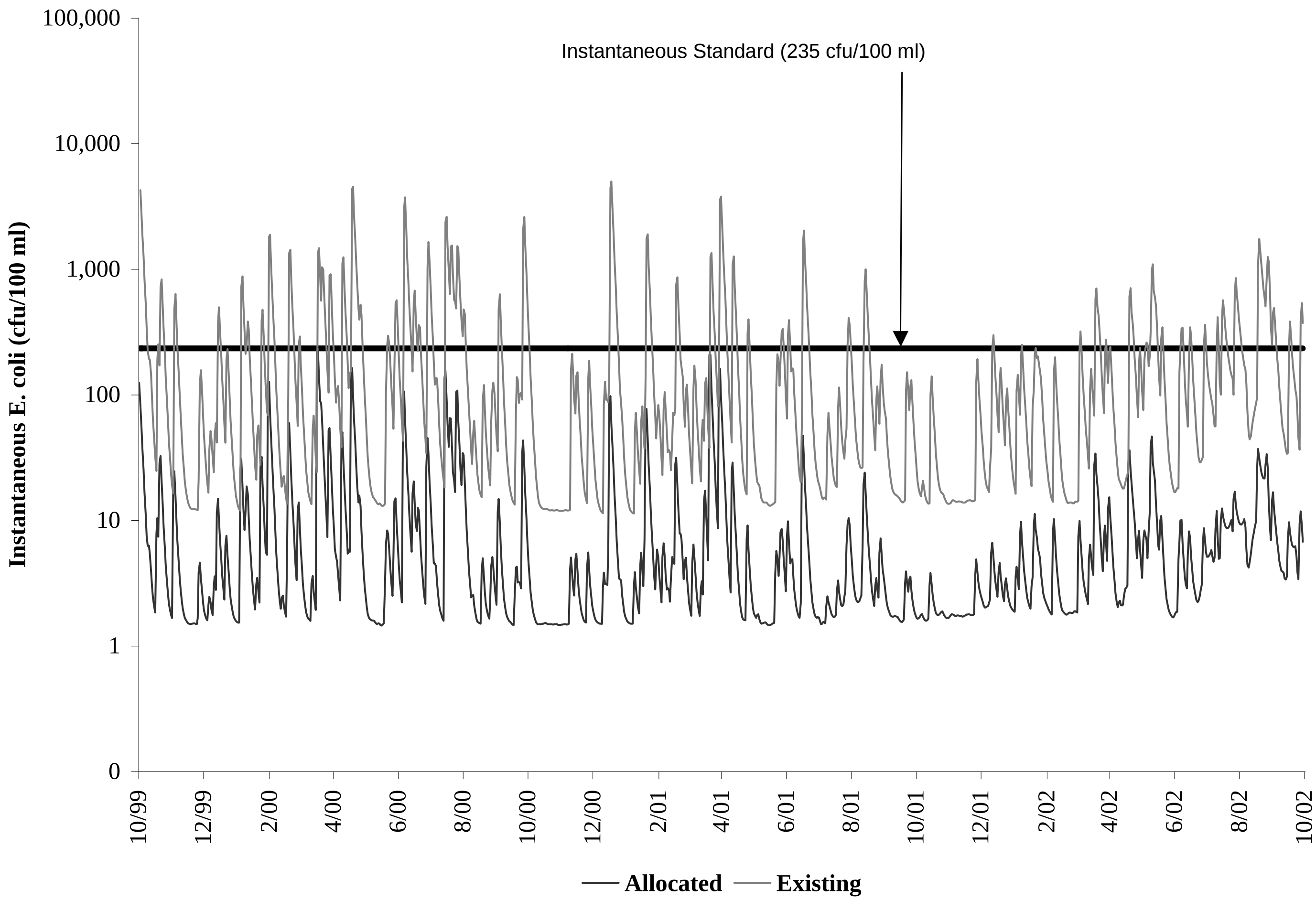

Figure 5.2 **Existing and allocation scenarios of *E. coli* concentrations in subwatershed 16, Big & Little Lickinghole Creeks impairment.**

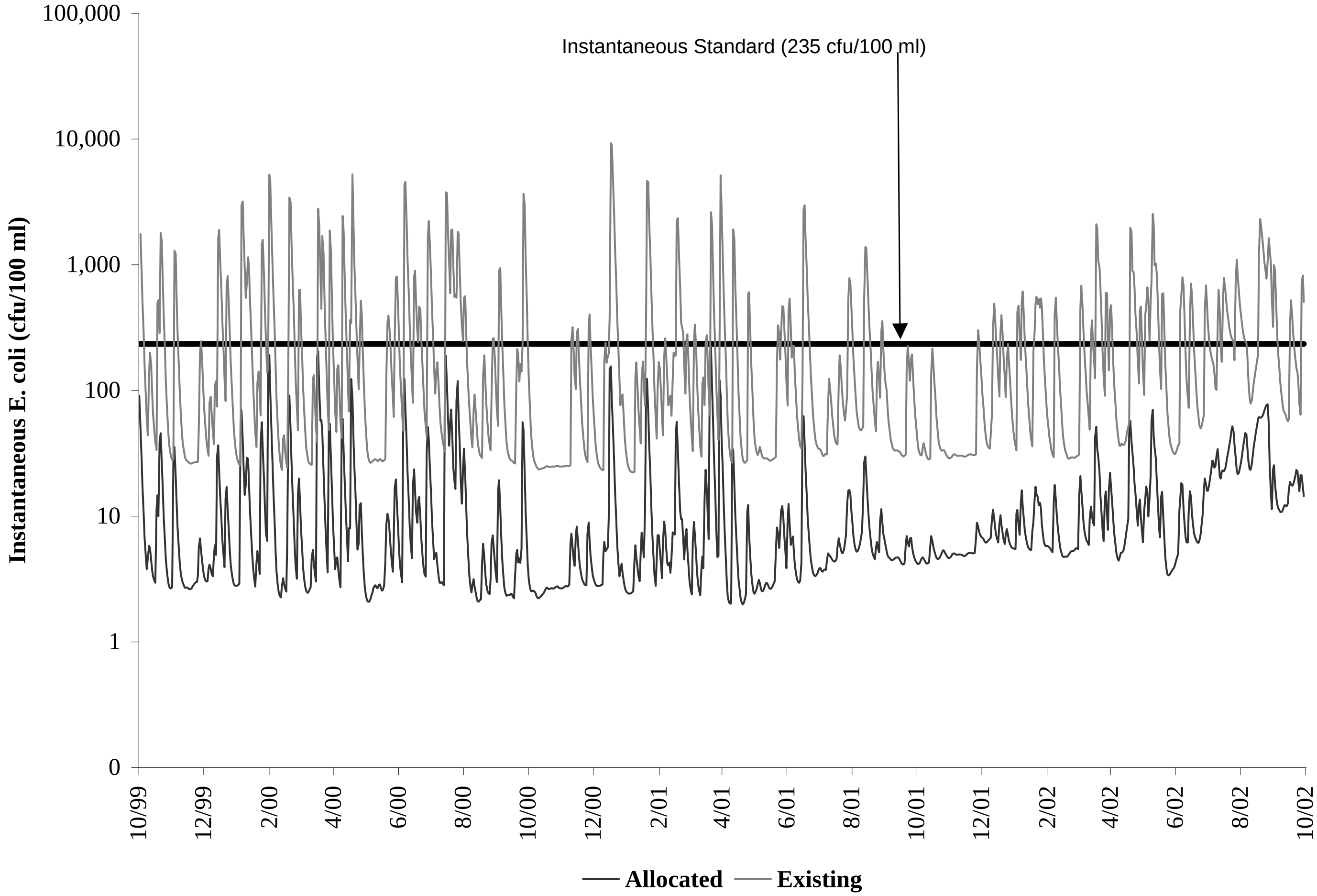

Figure 5.3 Existing and allocation scenarios of *E. coli* concentrations in subwatershed 18, Beaverdam Creek impairment.

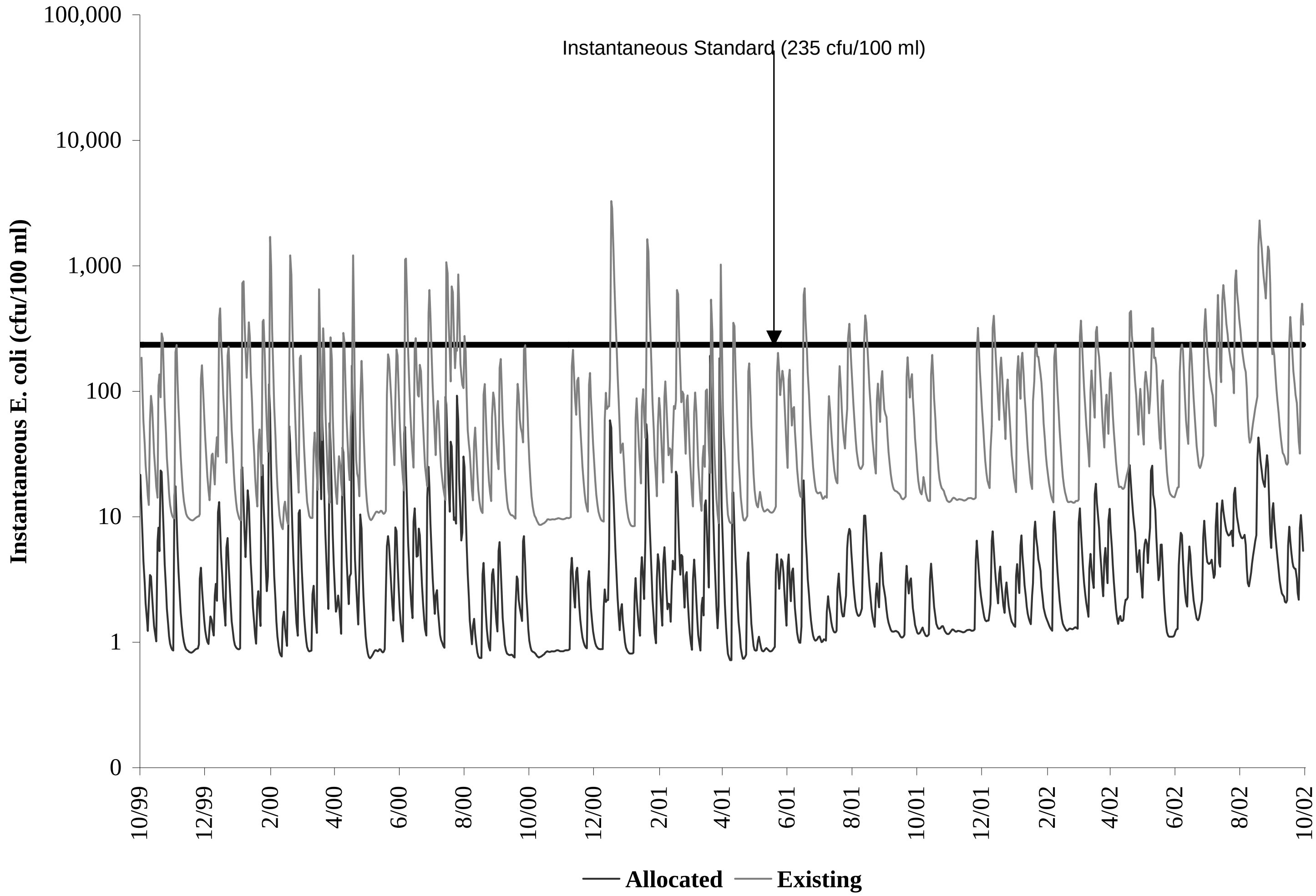

Figure 5.4 Existing and allocation scenarios of *E. coli* concentrations in subwatershed 19, Fine Creek impairment.

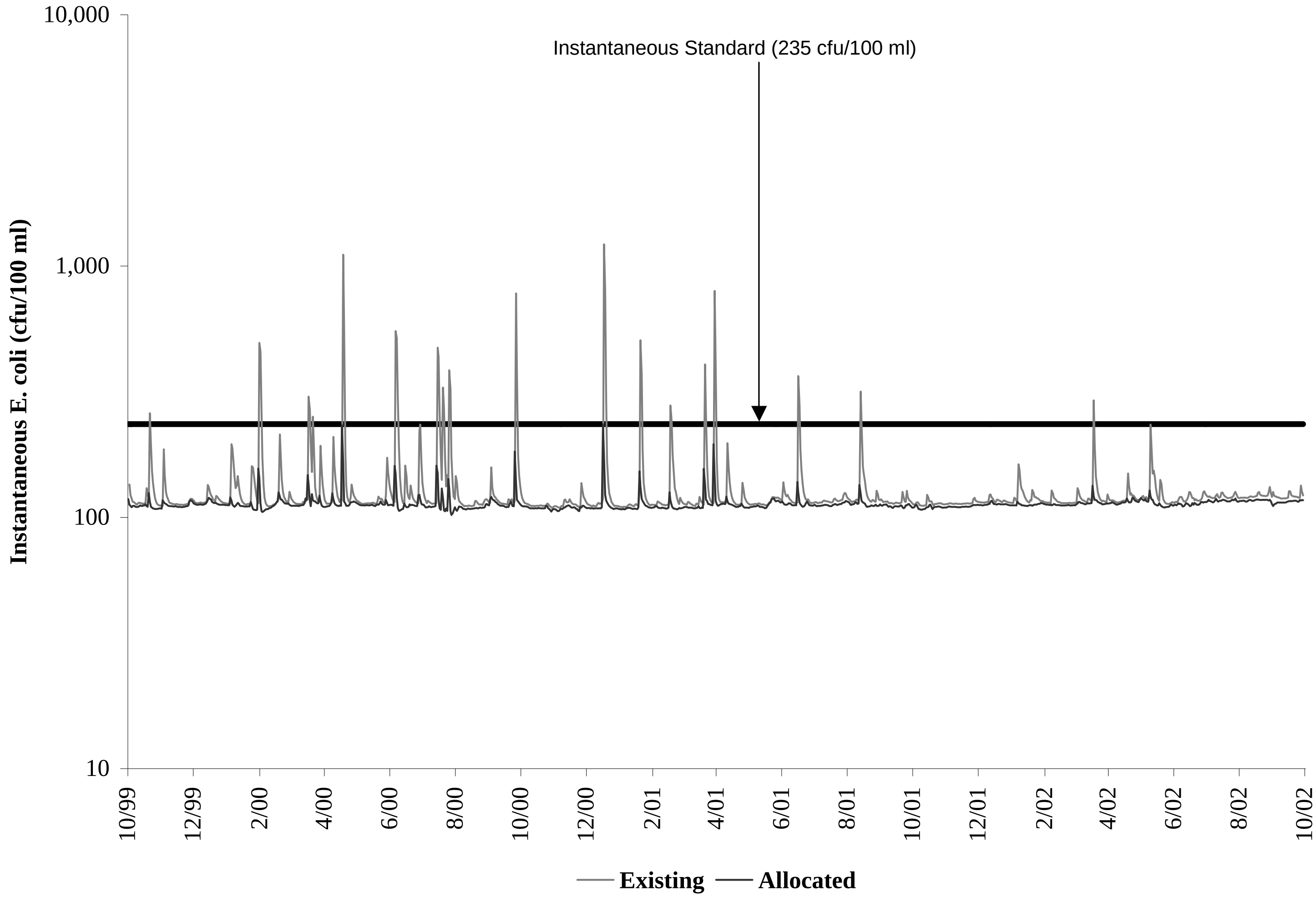

Figure 5.5 **Existing and allocation scenarios of *E. coli* concentrations in subwatershed 4 (H33R-01), Upper James River impairment, H33R-01.**

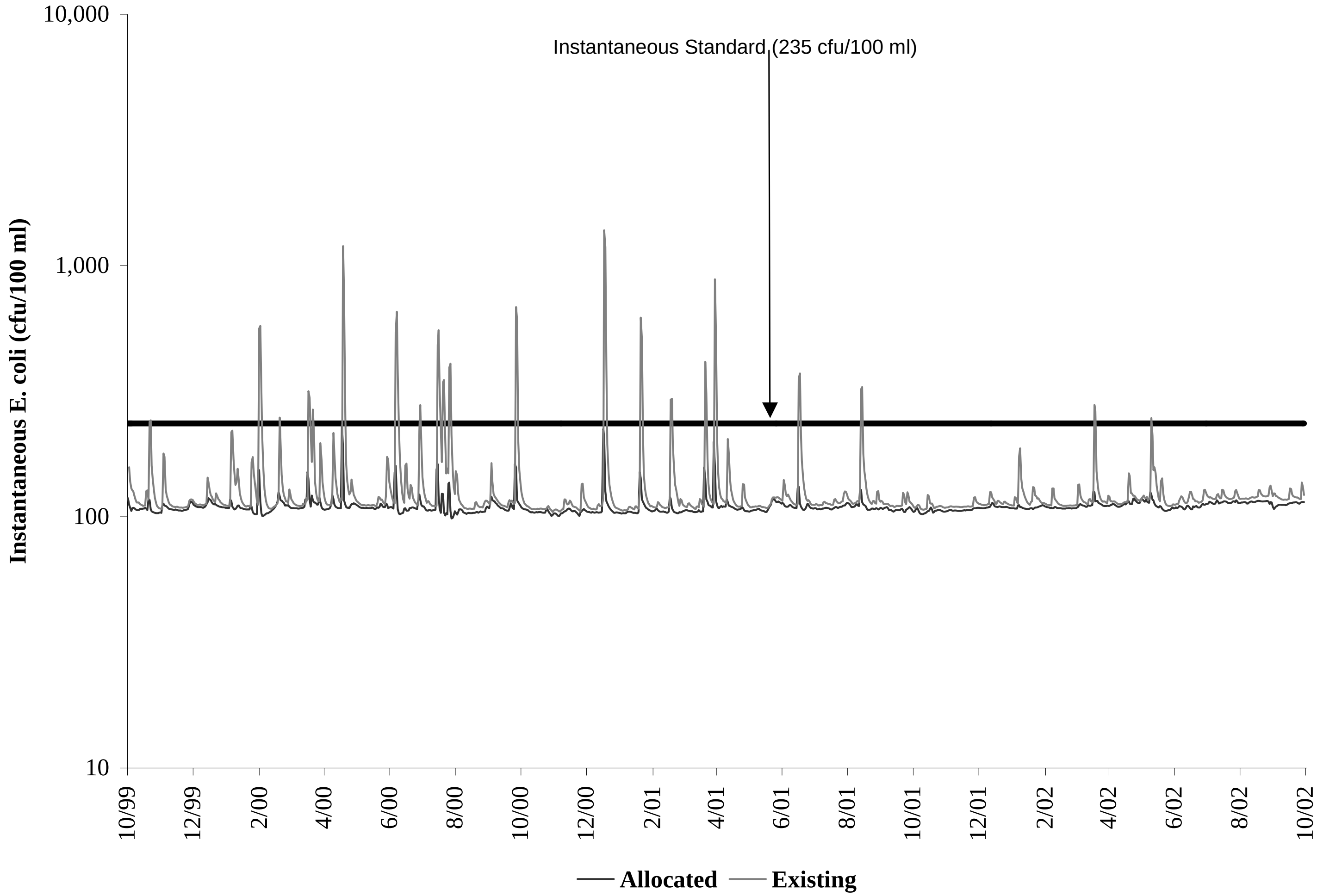

Figure 5.6 **Existing and allocation scenarios of *E. coli* concentrations in subwatershed 5 (H38R-04), lower James River impairment, H38R-04.**

Figures 5.7 through 5.12 contain monthly geometric mean concentrations for existing and allocated conditions for all impairments in the James River and Tributaries – Lower Piedmont Region. Existing conditions appear in gray, with allocated conditions in black. The monthly geometric mean is calculated from the daily average *E. coli* concentration, predicted by the water quality model, and is grouped by calendar month.

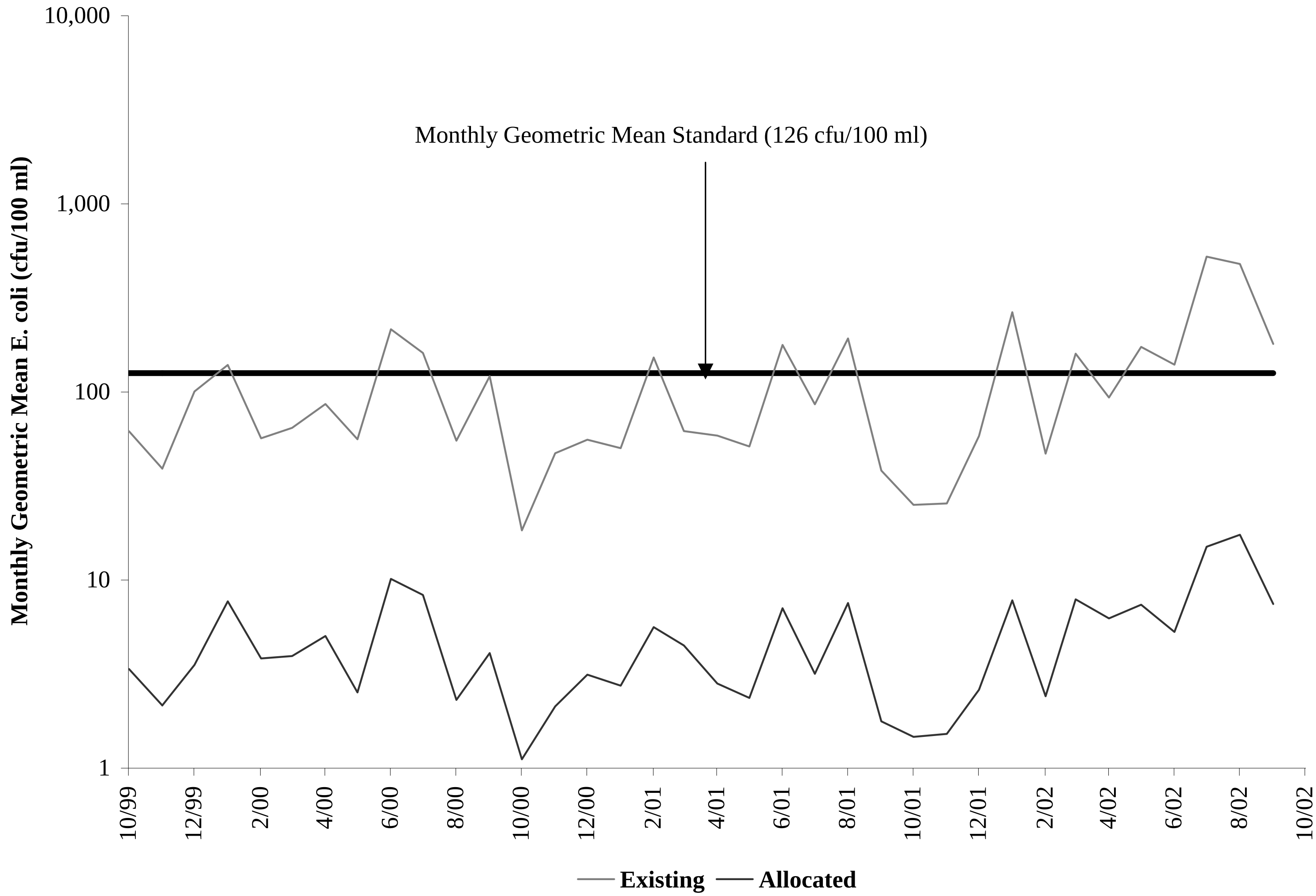

Figure 5.7 Existing and allocation scenarios of *E. coli* concentrations in subwatershed 10, Byrd Creek impairment.

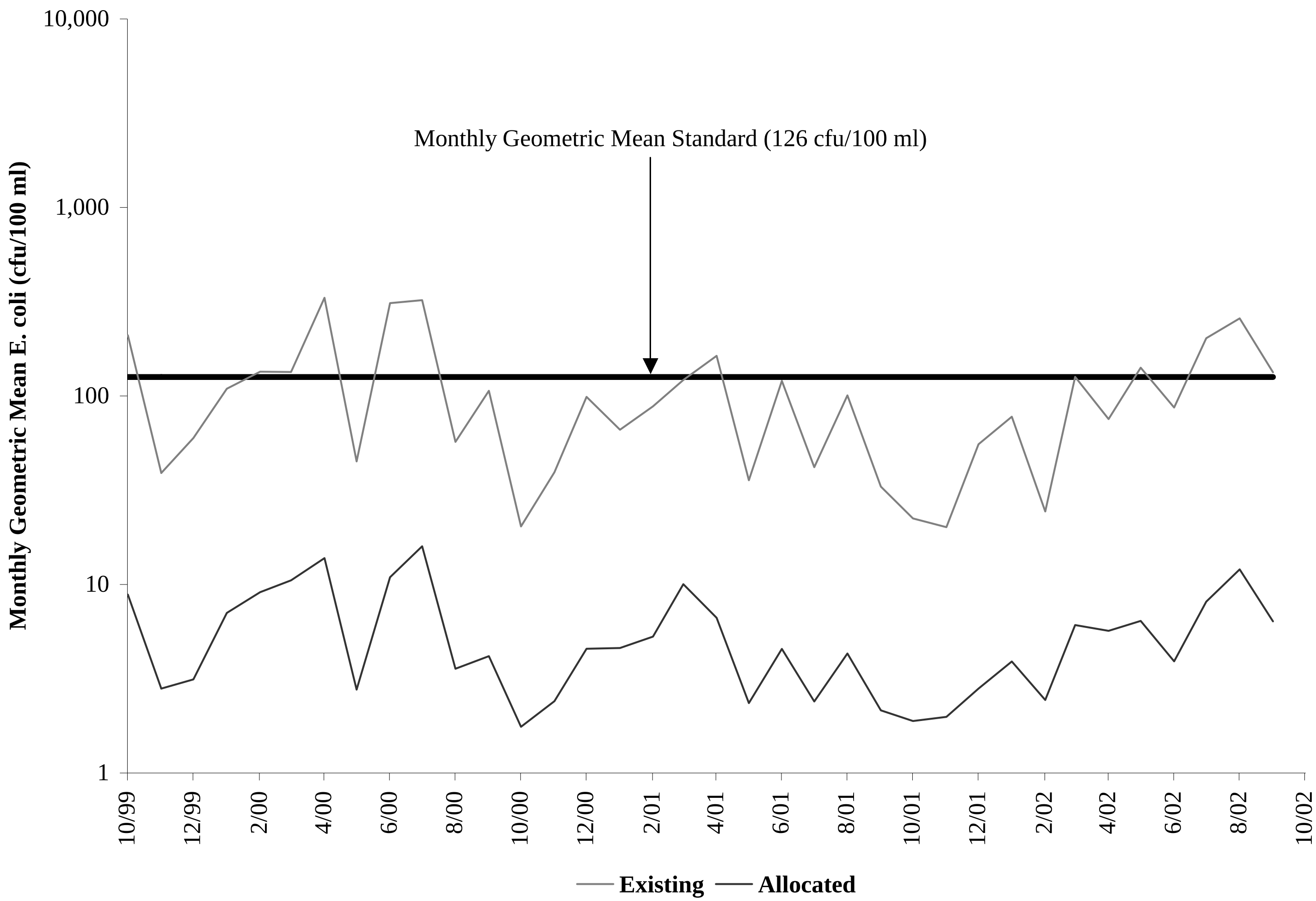

Figure 5.8 Existing and allocation scenarios of *E. coli* concentrations in subwatershed 16, Big & Little Lickinghole Creeks impairment.

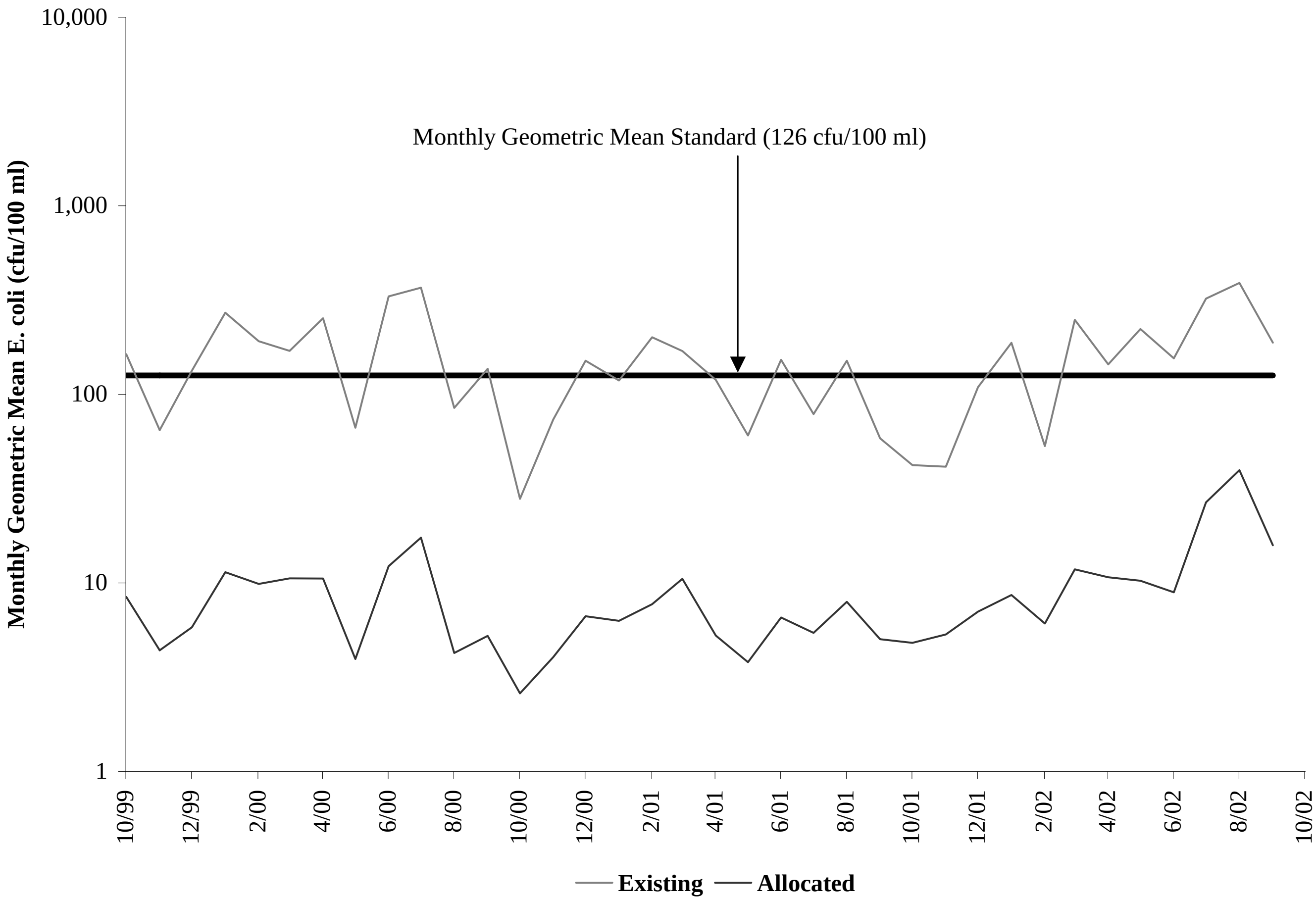

Figure 5.9 Existing and allocation scenarios of *E. coli* concentrations in model subwatershed 18, Beaverdam Creek impairment.

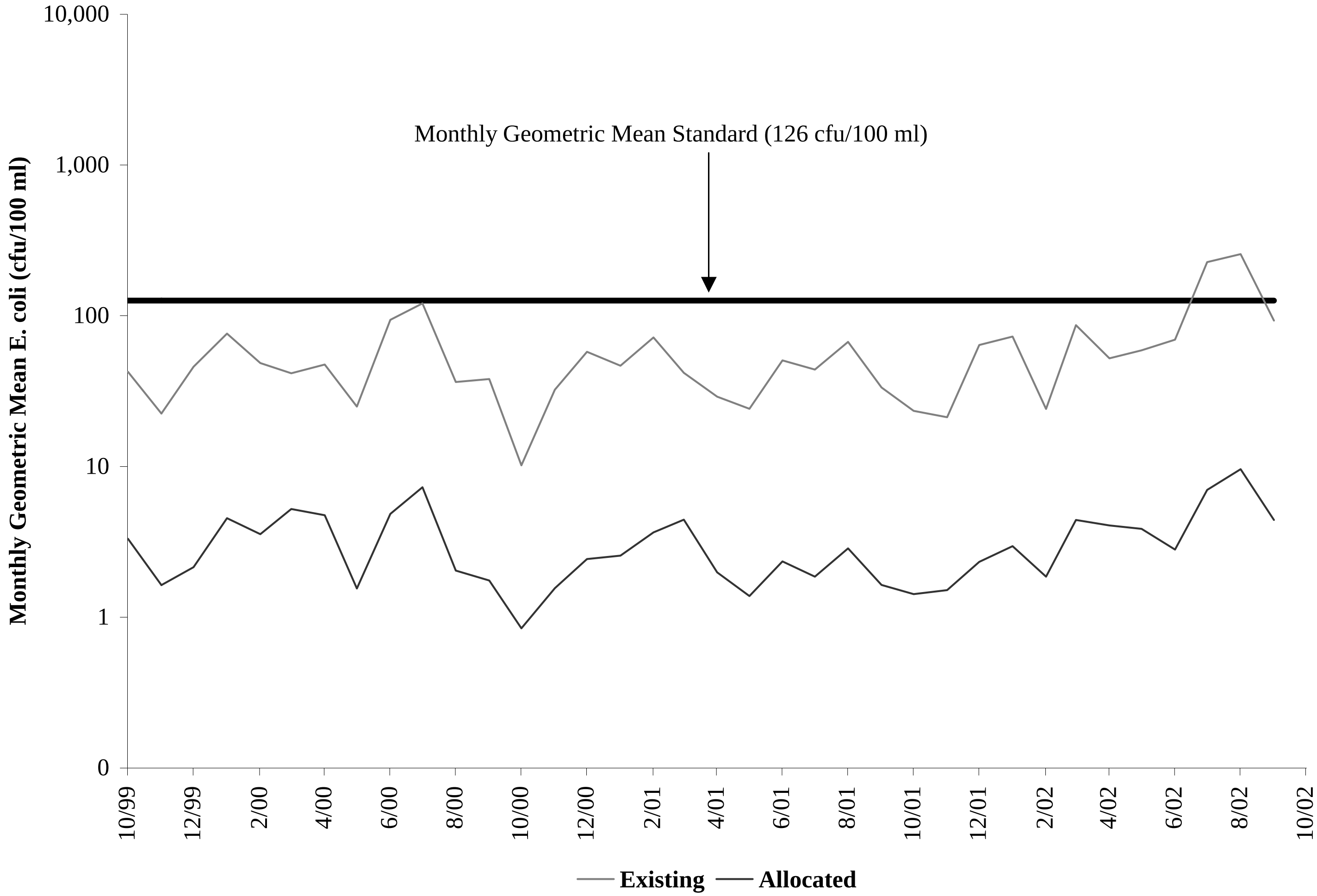

Figure 5.10 Existing and allocation scenarios of *E. coli* concentrations in subwatershed 19, Fine Creek impairment.

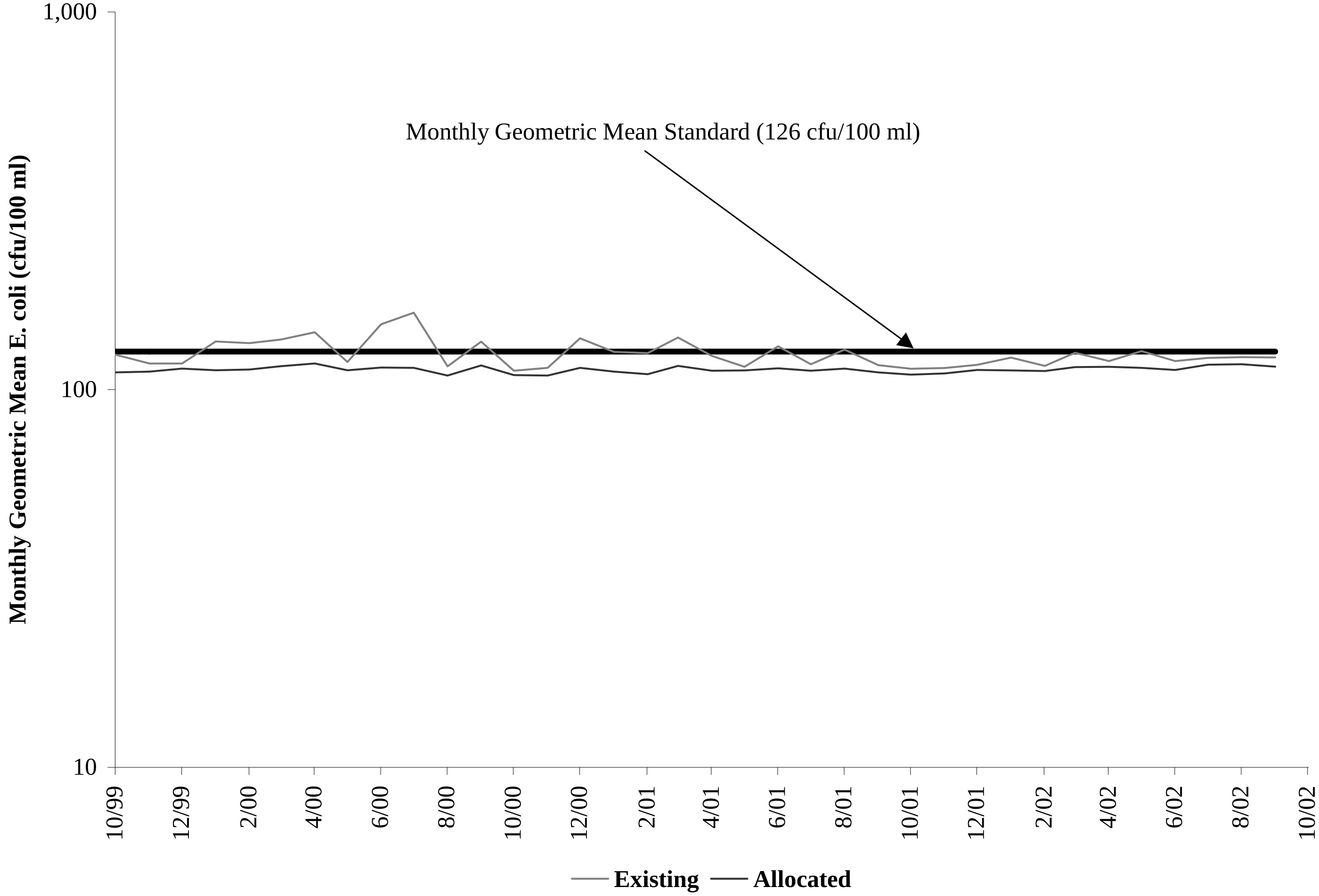

Figure 5.11 Existing and allocation scenarios of *E. coli* concentrations in subwatershed 4 (H33R-01), James River impairment.

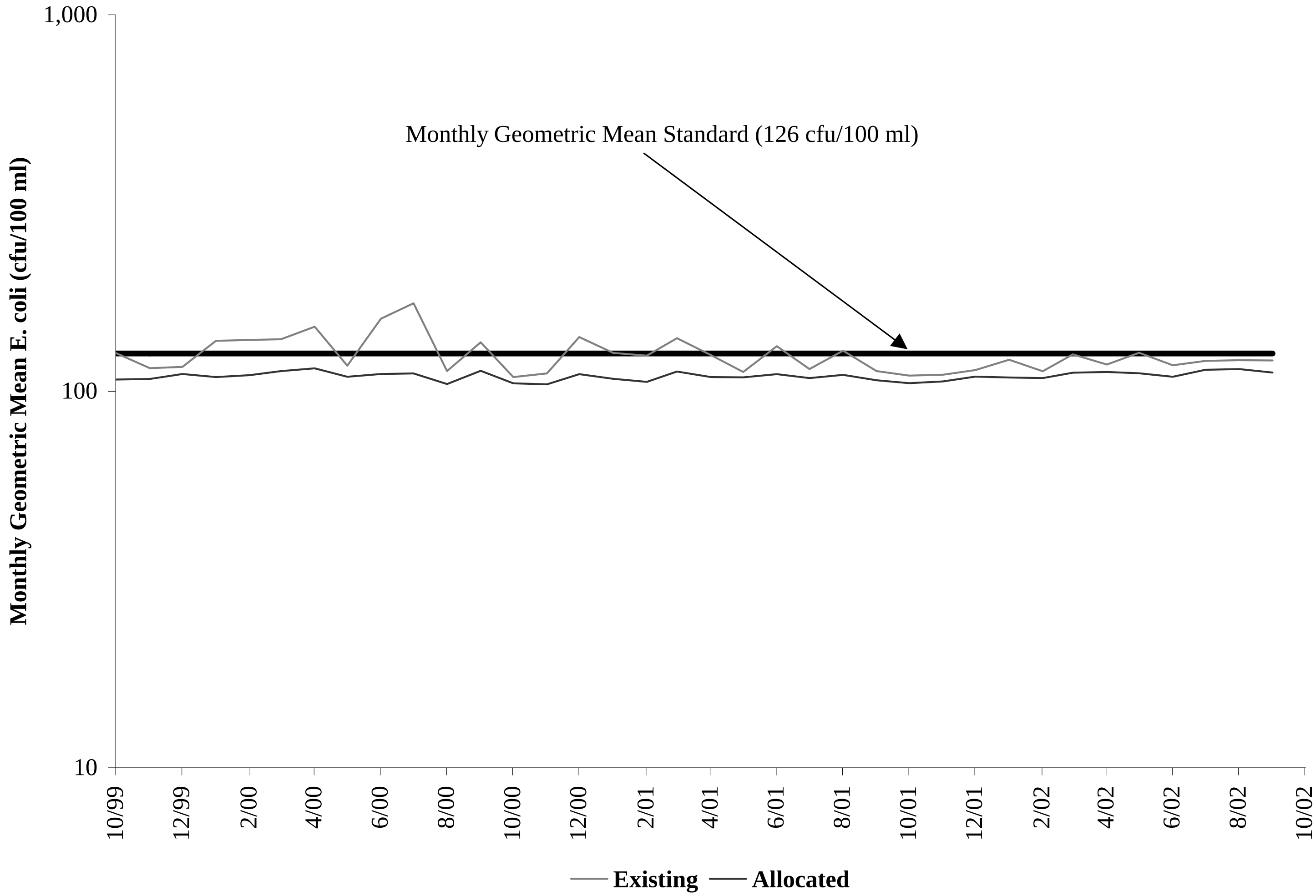

Figure 5.12 Existing and allocation scenarios of *E. coli* concentrations in subwatershed 5 (H38R-04), James River impairment.

Tables 5.7 through 5.12 contain estimates of existing and allocated in-stream *E. coli* loads for all six impairment outlets reported as average annual cfu per year. These loads are distributed based on their land-based origins, as opposed to their source origins. The estimates in Tables 5.7 through 5.12 are generated from available data, and these values are specific to the impairment outlet for the allocation rainfall for the current land use distribution in the watershed. The percent reductions needed to meet zero percent violations of all applicable water quality standards are given in the final column.

Table 5.7 Estimated existing and allocated *E. coli* in-stream loads in the Byrd Creek impairment for final allocation.

Source	Total Annual Loading for Existing Run[1] (cfu/yr)	Total Annual Loading for Allocation Run[1] (cfu/yr)	Percent Reduction
Land Based			
Barren	1.32E+10	3.84E+09	71.0%
Commercial	3.72E+12	3.72E+10	99.0%
Cropland	2.30E+12	2.30E+10	99.0%
Forest	2.59E+13	7.50E+12	71.0%
Livestock Access	3.72E+12	3.72E+10	99.0%
Low Density Residential	4.90E+12	4.90E+10	99.0%
Pasture	1.10E+14	1.10E+12	99.0%
Wetland	1.69E+12	4.91E+11	71.0%
Direct			
Human	1.68E+13	0.00E+00	100.0%
Livestock	2.25E+13	0.00E+00	100.0%
Wildlife	9.37E+11	2.72E+11	71.0%
Permitted Sources	1.08E+11	1.08E+11	0%
Total Loads	**1.92E+14**	**9.62E+12**	**99.3%**

[1]Permitted Sources was set equal to the WLA, which includes a value for future growth

Table 5.8 Estimated existing and allocated *E. coli* in-stream loads in the Big & Little Lickinghole Creeks impairment for final allocation.

Source	Total Annual Loading for Existing Run[1] (cfu/yr)	Total Annual Loading for Allocation Run[1] (cfu/yr)	Percent Reduction
Land Based			
Barren	7.37E+10	3.43E+10	53.5%
Commercial	9.42E+11	9.42E+09	99.0%
Cropland	6.55E+13	6.55E+11	99.0%
Forest	1.24E+13	5.78E+12	53.5%
Livestock Access	9.42E+11	9.42E+09	99.0%
Low Density Residential	5.08E+12	5.08E+10	99.0%
Pasture	4.08E+13	4.08E+11	99.0%
Wetland	1.18E+12	5.47E+11	53.5%
Direct			
Human	2.07E+13	0.00E+00	100.0%
Livestock	1.44E+13	0.00E+00	100.0%
Wildlife	8.64E+11	4.02E+11	53.5%
Permitted Sources	7.94E+10	7.94E+10	0%
Total Loads	**1.63E+14**	**7.98E+12**	**99.5%**

[1]Permitted Sources was set equal to the WLA, which includes a value for future growth

Table 5.9 Estimated existing and allocated *E. coli* in-stream loads in the Beaverdam Creek impairment for final allocation.

Source	Total Annual Loading for Existing Run[1] (cfu/yr)	Total Annual Loading for Allocation Run[1] (cfu/yr)	Percent Reduction
Land Based			
Barren	4.01E+10	9.23E+09	77.0%
Commercial	2.67E+12	2.67E+10	99.0%
Cropland	4.04E+13	4.04E+11	99.0%
Forest	1.43E+13	3.29E+12	77.0%
Livestock Access	2.67E+12	2.67E+10	99.0%
Low Density Residential	7.30E+12	7.30E+10	99.0%
Pasture	7.47E+13	7.47E+11	99.0%
Wetland	1.38E+12	3.18E+11	77.0%
Direct			
Human	5.57E+13	0.00E+00	100.0%
Livestock	3.69E+13	0.00E+00	100.0%
Wildlife	5.09E+11	1.17E+11	77.0%
Permitted Sources	3.13E+12	3.13E+12	0%
Total Loads	**2.40E+14**	**8.14E+12**	**99.7%**

[1]Permitted Sources was set equal to the WLA, which includes a value for future growth

Table 5.10 Estimated existing and allocated *E. coli* in-stream loads in the Fine Creek impairment for final allocation.

Source	Total Annual Loading for Existing Run[1] (cfu/yr)	Total Annual Loading for Allocation Run[1] (cfu/yr)	Percent Reduction
Land Based			
Barren	3.57E+10	1.68E+10	53.0%
Commercial	4.68E+11	4.68E+09	99.0%
Cropland	8.94E+10	8.94E+08	99.0%
Forest	6.50E+12	3.05E+12	53.0%
Livestock Access	4.68E+11	4.68E+09	99.0%
Low Density Residential	3.27E+12	3.27E+10	99.0%
Pasture	1.86E+13	1.86E+11	99.0%
Wetland	5.18E+11	2.43E+11	53.0%
Direct			
Human	1.01E+13	0.00E+00	100.0%
Livestock	8.11E+12	0.00E+00	100.0%
Wildlife	1.93E+11	9.08E+10	53.0%
Permitted Sources	3.66E+10	3.66E+10	0%
Total Loads	**4.84E+13**	**3.67E+12**	**99.3%**

[1]Permitted Sources was set equal to the WLA, which includes a value for future growth

Table 5.11 Estimated existing and allocated *E. coli* in-stream loads in the upper James River impairment (H33R-01) for final allocation.

Source	Total Annual Loading for Existing Run[1] (cfu/yr)	Total Annual Loading for Allocation Run[1] (cfu/yr)	Percent Reduction
Land Based			
Barren	1.84E+12	1.84E+12	0.0%
Commercial	4.37E+14	4.37E+13	90.0%
Cropland	1.36E+16	1.36E+15	90.0%
Forest	7.70E+14	7.70E+14	0.0%
Livestock Access	4.37E+14	4.37E+13	90.0%
Low Density Residential	8.05E+14	8.05E+13	90.0%
Pasture	1.44E+16	1.44E+15	90.0%
Wetland	4.86E+13	4.86E+13	0.0%
Direct			
Human	3.18E+14	0.00E+00	100.0%
Livestock	1.75E+14	7.36E+13	57.9%
Wildlife	5.84E+13	5.84E+13	0.0%
Permitted Sources	3.54E+11	3.54E+11	0%
Total Loads	**3.10E+16**	**3.92E+15**	**53.5%**

[1]Permitted Sources was set equal to the WLA, which includes a value for future growth

Table 5.12 Estimated existing and allocated *E. coli* in-stream loads in the lower James River impairment (H38R-04) for final allocation.

Source	Total Annual Loading for Existing Run[1] (cfu/yr)	Total Annual Loading for Allocation Run[1] (cfu/yr)	Percent Reduction
Land Based			
Barren	3.07E+12	3.07E+12	0.0%
Commercial	5.31E+14	3.72E+13	93.0%
Cropland	1.54E+16	1.08E+15	93.0%
Forest	1.06E+15	1.06E+15	0.0%
Livestock Access	5.31E+14	3.72E+13	93.0%
Low Density Residential	1.25E+15	8.77E+13	93.0%
Pasture	1.89E+16	1.32E+15	93.0%
Wetland	8.91E+13	8.91E+13	0.0%
Direct			
Human	4.25E+14	0.00E+00	100.0%
Livestock	3.11E+14	7.71E+13	75.2%
Wildlife	1.10E+14	1.10E+14	0.0%
Permitted Sources	7.92E+12	7.92E+12	0%
Total Loads	**3.86E+16**	**3.91E+15**	**68.3%**

[1]Permitted Sources was set equal to the WLA, which includes a value for future growth

Table 5.13, is know as the annual TMDL table, gives the number of cfu of *E. coli* that can reach the stream in a given year and still meet existing water quality standards. These numbers are divided into Waste Load Allocation (WLA) (the portion of fecal coliform that may come from permitted discharge sources) and Load Allocation (LA) (the portion of fecal coliform that may come from the non-permitted non-point sources existing in the watershed). This table also includes an entry representing an allocated amount of E. coli for future growth in the watershed in terms of more permitted discharge sources. It can be observed from this Table 5.13 that future growth load in the waste load allocation for Beaverdam Creek is relatively higher than future growth for the rest of the impairments. This is due to the current high effluent from point sources existing within Beaverdam watershed. Expected growth in bacteria loads from point sources is a function of existing loads from point sources within the watershed. Table 5.14 is the Daily TMDL table, where the daily TMDL is presented for the 99th percentile daily flow condition at the numeric water quality criterion of 235 cfu/100ml.

Tables 5.7 through 5.12 show the existing and allocated fecal coliform land-based and direct loads that are input into the HSPF model. On the other hand, Table 5.13 shows the final in-stream allocated bacteria loads. Values in Table 5.13 are output from the HSPF model and incorporate in-stream die-off and other hydrological and environmental processes involved during runoff and stream routing techniques within the HSPF model framework. The values in Tables 5.7 through 5.12 cannot therefore be directly compared to the values in Table 5.13.

Table 5.13 Average annual *E. coli* (cfu/year) modeled after TMDL allocation in the James River Tributaries – Lower Piedmont Region.

Impairment	TMDL Standard	WLA (cfu/year)	LA (cfu/year)	MOS	TMDL (cfu/year)
Byrd Creek	*E. coli*	1.08E+11	9.51E+12	Implicit	9.62E+12
VAG404239		*1.74E+09*			
VAG404240		*1.74E+09*			
VAG406343		*1.74E+09*			
VAG406344		*1.74E+09*			
VAG406345		*1.74E+09*			
VAG406346		*1.74E+09*			
VAG406347		*1.74E+09*			
Future Growth		*9.57E+10*			
Big & Little Lickinghole Creek	*E. coli*	7.94E+10	7.90E+12		7.98E+12
Future Growth		*7.94E+10*			
Beaverdam Creek	*E. coli*	3.13E+12	5.01E+12		8.14E+12
VA0020681		*3.76E+11*			
VA0006149		*1.04E+11*			
VA0023108		*3.48E+10*			
VA0063037		*6.96E+09*			
Future Growth		*2.61E+12*			
Fine Creek	*E. coli*	3.66E+10	3.63E+12		3.67E+12
Future Growth		*3.66E+10*			
James River (upper, H33R-01)	*E. coli*	3.54E+11	3.92E+15		3.92E+15
VA0062731		*2.17E+10*			
VA0088382		*3.48E+10*			
VAG404239		*1.74E+09*			
VAG404240		*1.74E+09*			
VAG406343		*1.74E+09*			
VAG406344		*1.74E+09*			
VAG406345		*1.74E+09*			
VAG406346		*1.74E+09*			
Future Growth		*2.83E+11*			
James River (lower, H38R-04)	*E. coli*	7.92E+12	3.91E+15		3.91E+15
VA0062731		*2.17E+10*			
VA0088382		*3.48E+10*			
VA0020656		*1.57E+11*			
VA0020699		*8.09E+11*			
VA0020702		*3.41E+11*			
VAG404239		*1.74E+09*			
VAG404240		*1.74E+09*			
VAG406343		*1.74E+09*			
VAG406344		*1.74E+09*			
VAG406345		*1.74E+09*			
VAG406346		*1.74E+09*			
VAG406347		*1.74E+09*			
VAG404226		*1.74E+09*			
Future Growth		*6.54E+12*			

Table 5.14 Daily *E. coli* (cfu/day) in the James River Tributaries – Lower Piedmont Region.

Impairment	TMDL (daily)[1] (cfu/day)	WLA (daily)[2] (cfu/day)	MOS	LA (daily) (cfu/day)
Byrd Creek	2.54E+12	2.96E+08	*Implicit*	2.53E+12
Big & Little Lickinghole Creeks	1.46E+12	2.18E+08		1.46E+12
Beaverdam Creek	9.59E+11	8.59E+09		9.50E+11
Fine Creek	4.88E+11	1.00E+08		4.88E+11
James River (upper, H33R-01)	1.14E+14	9.69E+08		1.14E+14
James River (lower, H38R-04)	1.28E+14	2.17E+10		1.28E+14

1 – The TMDL is presented for the 99th percentile daily flow condition at the numeric water quality criterion of 235 cfu/100ml. The TMDL is variable depending on flow conditions. The numeric water quality criterion will be used to assess progress toward TMDL goals.

2 – The WLA reflects existing, as well as an allocation for potential future permits issued for bacteria control. Any issued permit will include bacteria effluent limits in accordance with applicable permit guidance and will ensure that the discharge meets the applicable numeric water quality criteria for bacteria at the end-of-pipe.

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6. IMPLEMENTATION

Once the EPA has approved a TMDL, measures must be taken to reduce pollutant levels from both point and nonpoint sources in the stream. For point sources, all new or revised VPDES/NPDES permits must be consistent with the TMDL WLA pursuant to 40 CFR 122.44 (d)(1)(vii)(B) and must be submitted to the EPA for approval. The measures for nonpoint source reductions, which can include the use of better treatment technology and the installation of best management practices (BMPs), are implemented in an iterative process that is described along with specific BMPs in the implementation plan (IP). The process for developing an IP is described in the *Guidance Manual for Total Maximum Daily Load Implementation Plans* (July 2003). The guide is available upon request from the VADEQ and VADCR TMDL project staff or at http://www.deq.virginia.gov/tmdl/implans/ipguide.pdf. With successful completion of IPs, local stakeholders will have a blueprint to restore impaired waters and enhance the value of their land and water resources. Development of an approved implementation plan may also enhance opportunities for obtaining financial and technical assistance during implementation.

6.1 Staged Implementation

Virginia intends for the required bacteria reductions to be implemented in an iterative process that first addresses those sources with the largest impact on water quality. For example, in agricultural areas of the watershed, the most promising management practice is livestock exclusion from the streams. This has been shown to be very effective in lowering bacteria concentrations in streams, both by reducing the cattle direct deposits and by providing additional riparian buffers.

In both urban and rural areas, reducing the human bacteria loading from failing septic systems should be a primary implementation focus because of its health implications. This component could be implemented through education on septic tank pump-outs, a septic system repair/replacement program, and the use of alternative waste treatment systems.

In urban areas reducing the human bacteria loading from leaking sewer lines could be accomplished through a sanitary sewer inspection and management program. Best Management Practices (BMPs) effective for controlling urban wash-off from parking lots and roads that may be readily implemented can include more restrictive ordinances to reduce fecal loads from pets, improved garbage collection and control, and improved street cleaning.

The iterative implementation of BMPs in the watershed has several benefits:

1. It enables tracking of water quality improvements following BMP implementation through follow-up stream monitoring;
2. It provides a measure of quality control, given the uncertainties inherent in computer simulation modeling;
3. It provides a mechanism for developing public support through periodic updates on BMP implementation and water quality improvements;
4. It helps ensure that the most cost effective practices are implemented first; and
5. It allows for the evaluation of the adequacy of the TMDL in achieving water quality standards.

Watershed stakeholders will have the opportunity to participate in the development of the TMDL IP. While specific goals for BMP implementation will be established as part of the IP development, the following Stage 1 scenarios are targeted at controllable, anthropogenic bacteria sources and can serve as starting points for targeting BMP implementation activities.

6.2 Stage 1 Scenarios

The goal of Stage 1 scenarios is to reduce the bacteria loadings from controllable sources (excluding wildlife) such that violations of the single sample maximum criterion (235 cfu/100mL) are less than 10.5 percent. The Stage 1 scenarios were generated with the same model setup as was used for the TMDL allocation scenarios Tables 6.1 through 6.6).

Table 6.1 Reduction percentages for the Stage I implementation in Byrd Creek.

Scenario Number	Percent Reduction in Loading from Existing Condition						Percent Violations	
	Direct Wildlife Loads	NPS Forest/ Wetlands	Direct Livestock Loads	NPS Agricultural Land	NPS Residential/ Commercial Land	Direct Human Loads	Geometric Mean > 126 cfu/100ml	Single Sample > 235 cfu/100ml
7	0	0	99	78.2	78.2	100	0	10.41
8	0	0	90	75	50	100	5.56	10.32
9	0	0	80	80	80	100	5.56	9.95
11	0	0	0	0	91	100	5.56	10.32

Table 6.2 Reduction percentages for the Stage I implementation in Big & Little Lickinghole Creeks.

Scenario Number	Percent Reduction in Loading from Existing Condition						Percent Violations	
	Direct Wildlife Loads	NPS Forest/ Wetlands	Direct Livestock Loads	NPS Agricultural Land	NPS Residential/ Commercia l Land	Direct Human Loads	Geometric Mean > 126 cfu/100ml	Single Sample > 235 cfu/100ml
7	0	0	99	66	66	100	2.78	10.41
8	0	0	68	68	68	100	2.78	9.86
9	0	0	67	67	67	100	5.56	10.32
11	0	0	0	77	0	100	5.56	10.23

Table 6.3 Reduction percentages for the Stage I implementation in Beaverdam Creek.

Scenario Number	Percent Reduction in Loading from Existing Condition						Percent Violations	
	Direct Wildlife Loads	NPS Forest/ Wetlands	Direct Livestock Loads	NPS Agricultural Land	NPS Residential/ Commercial Land	Direct Human Loads	Geometric Mean > 126 cfu/100ml	Single Sample > 235 cfu/100ml
7	0	0	99	78	78	100	0	10.32
8	0	0	79	79	79	100	0	10.23
11	0	0	73	73	99	100	0	10.23

Table 6.4 Reduction percentages for the Stage I implementation in Fine Creek.

Scenario Number	Percent Reduction in Loading from Existing Condition						Percent Violations	
	Direct Wildlife Loads	NPS Forest/ Wetlands	Direct Livestock Loads	NPS Agricultural Land	NPS Residential/ Commercial Land	Direct Human Loads	Geometric Mean > 126 cfu/100ml	Single Sample > 235 cfu/100ml
7	0	0	11	11	11	100	5.56	10.14
9	0	0	99	8	8	100	5.56	10.41
11	0	0	0	15	0	100	5.56	10.32
13	0	0	0	0	15	100	5.56	10.23

Table 6.5 Reduction percentages for the Stage I implementation in upper James River impairment (H33R-01).

Scenario Number	Percent Reduction in Loading from Existing Condition						Percent Violations	
	Direct Wildlife Loads	NPS Forest/ Wetlands	Direct Livestock Loads	NPS Agricultural Land	NPS Residential/ Commercial Land	Direct Human Loads	Geometric Mean > 126 cfu/100ml	Single Sample > 235 cfu/100ml
2	0	0	0	0	0	100	30.56	3.29

Table 6.6 Reduction percentages for the Stage I implementation in lower James River impairment (H38R-04).

Scenario Number	Percent Reduction in Loading from Existing Condition						Percent Violations	
	Direct Wildlife Loads	NPS Forest/ Wetlands	Direct Livestock Loads	NPS Agricultural Land	NPS Residential/ Commercial Land	Direct Human Loads	Geometric Mean > 126 cfu/100ml	Single Sample > 235 cfu/100ml
2	0	0	0	0	0	100	30.56	3.93

6.3 Link to Ongoing Restoration Efforts

Implementation of this TMDL will contribute to ongoing water quality improvement efforts aimed at restoring water quality in Virginia's streams. Several BMPs known to be effective in controlling bacteria have been identified for implementation as part of the Tributary Strategy for the James River. For example, management of on-site waste management systems, management of livestock and manure, and pet waste management are among the components of the strategy described under nonpoint source implementation mechanisms. Up-to-date information on the tributary strategy implementation process can be found on the tributary strategy web site at: http://www.snr.state.va.us/Initiatives/WaterQuality/FinalizedTribStrats/james.pdf.

6.4 Reasonable Assurance for Implementation

6.4.1 Follow-Up Monitoring

Following TMDL development, the VADEQ will make every effort to continue to monitor the impaired stream in accordance with its ambient monitoring program. VADEQ's Ambient Watershed Monitoring Plan for conventional pollutants calls for watershed monitoring to take place on a rotating basis, bi-monthly for two consecutive years of a six-year cycle. In accordance with Guidance Memo No. 03-2004 (VADEQ, 2003), during periods of reduced resources, monitoring can temporarily discontinue until the TMDL staff determines that implementation measures to address the source(s) of impairments are being installed. Monitoring can resume at the start of the following fiscal year, next scheduled monitoring station rotation, or where deemed necessary by the regional office or TMDL staff, as a new special study.

The purpose, location, parameters, frequency, and duration of the monitoring will be determined by the VADEQ staff, in cooperation with the VADCR staff, the IP Steering Committee, and local stakeholders. Whenever possible, the location of the follow-up monitoring station(s) will be the same as the listing station. At a minimum, the monitoring station must be representative of the original impaired segment. The details of the follow-up monitoring will be outlined in the Annual Water Monitoring Plan prepared by each VADEQ Regional Office. Other agency personnel, watershed stakeholders, etc. may provide input on the Annual Water Monitoring Plan. These recommendations must be made to the VADEQ regional TMDL coordinator by September 30 of each year.

VADEQ staff, in cooperation with VADCR staff, the IP Steering Committee and local stakeholders, will continue to use data from the ambient monitoring stations to evaluate reductions in pollutants ("water quality milestones" as established in the IP), the effectiveness of the TMDL in attaining and maintaining water quality standards, and the success of implementation efforts. Recommendations may then be made, to target implementation efforts in specific areas and continue or discontinue monitoring at follow-up stations.

In some cases watersheds will require monitoring above and beyond what is included in the VADEQ's standard monitoring plan. Ancillary monitoring by citizens, watershed groups, local government or universities is an option that may be used in such cases. An effort should be made to ensure that ancillary monitoring follows established QA/QC guidelines in order to maximize compatibility with VADEQ monitoring data. In instances where citizens' monitoring data is not available and additional monitoring is needed to assess the effectiveness of targeting efforts, TMDL administrators may request that the monitoring managers in each regional office increase the number of stations or monitor existing stations at a higher frequency in the watershed. The additional monitoring beyond the original bimonthly single station monitoring will be contingent on staff resources and available laboratory budget. More information on citizen monitoring in Virginia and QA/QC guidelines is available at http://www.deq.virginia.gov/cmonitor/.

To demonstrate that the watershed is meeting water quality standards in watersheds where corrective actions have taken place (whether or not a TMDL or TMDL IP has been completed), the VADEQ must meet the minimum data requirements from the original listing station or a station representative of the originally listed segment. The minimum data requirement for conventional pollutants (bacteria, dissolved oxygen, etc.) is bimonthly monitoring for two consecutive years. For biological monitoring, the minimum requirement is two consecutive samples (one in the spring and one in the fall) in a one-year period.

6.4.2 Regulatory Framework

While section 303(d) of the Clean Water Act and current EPA regulations do not require the development of TMDL IPs as part of the TMDL process, they do require reasonable assurance that the load and wasteload allocations can and will be implemented. The EPA also requires that all new or revised National Pollutant Discharge Elimination System

(NPDES) permits be consistent with the TMDL WLA pursuant to 40 CFR §122.44 (d)(1)(vii)(B). All such permits should be submitted to the EPA for review.

Virginia's 1997 Water Quality Monitoring, Information and Restoration Act (WQMIRA) directs the State Water Control Board (SWCB) to "develop and implement a plan to achieve fully supporting status for impaired waters" (Section 62.1-44.19.7). WQMIRA also establishes that the IP shall include the date of expected achievement of water quality objectives, measurable goals, corrective actions necessary, the associated costs, benefits, and environmental impacts of addressing the impairments. The EPA outlines the minimum elements of an approvable IP in its 1999 *Guidance for Water Quality-Based Decisions: The TMDL Process*. The listed elements include implementation actions/management measures, timelines, legal or regulatory controls, time required to attain water quality standards, monitoring plans, and milestones for attaining water quality standards.

For the implementation of the WLA component of the TMDL, the Commonwealth intends to utilize the Virginia Pollutant Discharge Elimination System (VPDES) program, which typically includes consideration of the WQMIRA requirements during the permitting process. Requirements of the permit process should not be duplicated in the TMDL process and with the exception of stormwater related permits, permitted sources are not usually addressed during the development of a TMDL IP.

For the implementation of the TMDL's LA component, at a minimum a TMDL IP addressing the WQMIRA requirements will be developed. The municipal storm sewer systems (MS4s) are covered by NPDES permits and are an exception as they are expected to be included in TMDL implementation plans as described in the stormwater permit section below.

Watershed stakeholders will have opportunities to provide input and to participate in the development of the TMDL IP. Regional and local offices of VADEQ, VADCR, and other cooperating agencies are technical resources to assist in this endeavor.

In response to a Memorandum of Understanding (MOU) between EPA and VADEQ, VADEQ submitted a draft Continuous Planning Process to EPA in which VADEQ commits to regularly updating the state’s Water Quality Management Plans (WQMPs). Thus, the WQMPs will serve as the repository for all TMDLs and TMDL implementation plans developed within a river basin.

The VADEQ staff will present both EPA-approved TMDLs and TMDL IPs to the SWCB for inclusion in the appropriate WQMP, in accordance with the Clean Water Act’s Section 303(e) and Virginia’s Public Participation Guidelines for Water Quality Management Planning.

The VADEQ staff will also request that the SWCB adopt TMDL WLAs as part of the Water Quality Management Planning Regulation (9VAC 25-720) except in those cases when permit limitations are equivalent to numeric criteria contained in the Virginia Water Quality Standards, as is the case for bacteria. This regulatory action is in accordance with §2.2-4006A.4.c and §2.2-4006B of the Code of Virginia. SWCB actions relating to water quality management planning are described in the public participation guidelines referenced above and can be found on the VADEQ’s web site at http://www.deq.state.va.us/tmdl/pdf/ppp.pdf

6.4.3 Stormwater Permits

The VADEQ and VADCR coordinate separate state programs that regulate the management of pollutants carried by stormwater runoff. The VADEQ regulates stormwater discharges associated with "industrial activities", while the VADCR regulates storm water discharges from construction sites, and from MS4s.

EPA approved the VADCR's VPDES stormwater program on December 30, 2004. The VADCR's regulations became effective on January 29, 2005. The VADEQ is no longer the regulatory agency responsible for administration and enforcement of the VPDES MS4 and construction storm water permitting programs. More information is available on the VADCR's web site through the following link:
http://www.dcr.virginia.gov/sw/vsmp

It is the intention of the Commonwealth that the TMDL be implemented using existing regulations and programs. One of these regulations is VADCR's Virginia Stormwater Management Program (VSMP) Permit Regulation (4 VAC 50-60-10 et. seq). Section 4VAC 50-60-380 describes the requirements for stormwater discharges. Federal regulations state (40 CFR §122.44(k)) that NPDES permit conditions may consist of "Best management practices to control or abate the discharge of pollutants when:…(2) Numeric effluent limitations are infeasible,…".

For MS4/VSMP general permits the Commonwealth expects the permittee to specifically address the TMDL wasteload allocations for stormwater through the implementation of programmatic BMPs. BMP effectiveness would be determined through ambient in-stream monitoring. This is in accordance with recent EPA guidance (EPA Office of Water, 2002). If future monitoring indicates no improvement in stream water quality, the permit could require the MS4 to expand or better tailor its stormwater management program to achieve the TMDL wasteload allocation. However, only failing to implement the programmatic BMPs identified in the modified stormwater management program would be considered a violation of the permit. The VADEQ acknowledges that it may not be possible to meet the existing water quality standard because of the wildlife issue associated with a number of bacteria TMDLs. At some future time it may become necessary to investigate the stream's use designation and adjust the water quality criteria through a Use Attainability Analysis (UAA).

Wasteload allocations for stormwater discharges from storm sewer systems covered by a MS4 permit will be addressed in TMDL IPs. An implementation plan will identify types of corrective actions and strategies to obtain the wasteload allocation for the pollutant causing the water quality impairment. Permittees need to participate in the development of TMDL IPs since recommendations from the process may result in modifications to the stormwater management plan in order to meet the TMDL.

Additional information on Virginia's Stormwater Management program and a downloadable menu of Best Management Practices and Measurable Goals Guidance can be found at http://www.dcr.virginia.gov/sw/stormwat.htm.

6.4.4 Implementation Funding Sources

Cooperating agencies, organizations and stakeholders must identify potential funding sources available for implementation during the development of the IP in accordance with the *Guidance Manual for Total Maximum Daily Load Implementation Plans*. Potential sources for implementation may include the U.S. Department of Agriculture's Conservation Reserve Enhancement and Environmental Quality Incentive Programs, EPA Section 319 funds, the Virginia State Revolving Loan Program, Virginia Agricultural Best Management Practices Cost-Share Programs, the Virginia Water Quality Improvement Fund, tax credits, and landowner contributions. The *Guidance Manual for Total Maximum Daily Load Implementation Plans* also contains additional information on funding sources, as well as government agencies that might support implementation efforts and suggestions for integrating TMDL implementation with other watershed planning efforts.

6.4.5 Attainability of Primary Contact Recreation Use

In some streams for which TMDLs have been developed, water quality modeling indicates that even after removal of all bacteria sources (other than wildlife), the stream will not attain standards under all flow regimes at all times. These streams may not be able to attain standards without some reduction in the wildlife load.

With respect to these potential reductions in bacteria loads attributed to wildlife, neither the State of Virginia nor the EPA are proposing the elimination of wildlife to allow for the attainment of water quality standards. However, if bacteria levels remain high and localized overabundant populations of wildlife are identified as the source, then measures to reduce such populations may be an option if undertaken in consultation with the Department of Game and Inland Fisheries (DGIF) or the United States Fish and Wildlife Service (USFWS). Additional information on DGIF's wildlife programs can be found at http://www.dgif.virginia.gov/hunting/va_game_wildlife/. While managing overpopulations of wildlife remains an option to local stakeholders, the reduction of wildlife or changing a natural background condition is not the intended goal of a TMDL.

In the latest triennial water quality standards review Virginia proposed a new "secondary contact" category for protecting the recreational use in state waters to address the issue of non-attainability of the primary contact criteria. On March 25, 2003, the Virginia SWCB adopted criteria for "secondary contact recreation" which means "a water-based form of recreation, the practice of which has a low probability for total body immersion or ingestion of waters (examples include but are not limited to wading, boating and fishing)". These new criteria became effective on February 12, 2004 and can be found at http://www.deq.virginia.gov/wqs/rule.html.

In order for the new criteria to apply to a specific stream segment the primary contact recreational use must be removed. To remove a designated use, the state must demonstrate: 1) that the use is not an existing use; 2) that downstream uses are protected; and 3) that the source of contamination is natural and uncontrollable by effluent limitations or by implementing cost-effective and reasonable BMPs for nonpoint source control (9 VAC 25-260-10). This information is collected through a UAA. All site-specific criteria or designated use changes must be adopted as amendments to the water quality standards regulations. Watershed stakeholders and the EPA will be able to provide comment during this process. Additional information can be obtained at http://www.deq.virginia.gov/wqs/WQS03AUG.pdf.

Based upon the new criteria, the process to address potentially unattainable reductions begins with the development of a Stage 1 scenario such as those presented previously in this chapter. The pollutant reductions in the Stage 1 scenario are targeted primarily at the controllable, anthropogenic bacteria sources identified in the TMDL, setting aside control strategies for wildlife (except for cases of nuisance populations). During the implementation of the Stage 1 scenario, all controllable sources would be reduced to the maximum extent practicable using the iterative approach described in Section 6.1 above. The VADEQ will re-assess water quality in the stream during and subsequent to the implementation of the Stage 1 scenario to determine if the water quality standard is attained. This effort will also evaluate if the modeling assumptions were correct. If water quality standards are not being met and no additional cost-effective and reasonable

BMPs can be identified, a UAA may be initiated with the goal of re-designating the stream for secondary contact recreation.

7. PUBLIC PARTICIPATION

Public participation during TMDL development for the James River and Tributaries – Lower Piedmont Region was encouraged; a summary of the meetings is presented in Table 7.1. The first public meeting was held at the Goochland County Administration Building in Goochland, Virginia on July 19, 2006; 11 people attended, including 2 landowners, 1 consultant, and 8 agency representatives. The meeting was publicized by placing notices in the Virginia Register, and electronic mail advertisement to all agencies.

Table 7.1 Public participation during TMDL development for the James River and Tributaries – Lower Piedmont Region.

Date	Location	Attendance[1]	Type	Format
7/19/2006	Goochland County Admin. Building 1800 Sandy Hook Rd. Goochland, VA	11	First Public Meeting	Open to public at large
7/19/2006	Goochland County Admin. Building 1800 Sandy Hook Rd. Goochland, VA	10	First TAC Meeting	
1/31/2008	Goochland County Admin. Building 1800 Sandy Hook Rd. Goochland, VA	7	Final Public Meeting	Open to public at large
1/31/2008	Goochland County Admin. Building 1800 Sandy Hook Rd. Goochland, VA	12	Final TAC Meeting	

[1]The number of attendants is estimated from sign up sheets provided at each meeting. These numbers are known to underestimate the actual attendance.

The first Technical Advisory Committee (TAC) meeting also took place on July 19, 2006 in the Goochland County Administration Building in Goochland, Virginia. The meeting was attended by 10 people, including one consultant, and 9 agency representatives. The meeting was publicized by placing notices in the Virginia Register, and electronic mail advertisement to all agencies.

The final public meeting was held at the Goochland County Administration Building in Goochland, Virginia on January 31, 2008; 7 people attended, including 1 landowners, 1 consultant, and 5 agency representatives. The meeting was publicized by placing notices in the Virginia Register, and electronic mail advertisement to all agencies. The final Technical Advisory Committee (TAC) meeting also took place on January 31, 2008 in the Goochland County Administration Building in Goochland, Virginia. The meeting was attended by 12 people, including 1 consultant, and 10 agency representatives. The meeting was publicized by placing notices in the Virginia Register, and electronic mail advertisement to all agencies.

Public participation during the implementation plan development process will include the formation of a stakeholders' committee as well as open public meetings. Public participation is critical to promote reasonable assurances that the implementation activities will occur. A stakeholders' committee will have the express purpose of formulating the TMDL Implementation Plan. The major stakeholders were identified during the development of this TMDL. The committee will consist of, but not be limited to, representatives from VADEQ, VADCR, and local governments. This committee will have the responsibility for identifying corrective actions that are founded in practicality, establishing a time line to insure expeditious implementation, and setting measurable goals and milestones for attaining water quality standards.

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GLOSSARY

Note: All entries in italics are taken from USEPA (1998).

303(d). A section of the Clean Water Act of 1972 requiring states to identify and list water bodies that do not meet the states' water quality standards.

Allocations. *That portion of a receiving water's loading capacity attributed to one of its existing or future pollution sources (nonpoint or point) or to natural background sources. (A wasteload allocation [WLA] is that portion of the loading capacity allocated to an existing or future point source, and a load allocation [LA] is that portion allocated to an existing or future nonpoint source or to natural background levels. Load allocations are best estimates of the loading, which can range from reasonably accurate estimates to gross allotments, depending on the availability of data and appropriate techniques for predicting loading.)*

Ambient water quality. *Natural concentration of water quality constituents prior to mixing of either point or nonpoint source load of contaminants. Reference ambient concentration is used to indicate the concentration of a chemical that will not cause adverse impact on human health.*

Anthropogenic*. Pertains to the [environmental] influence of human activities.*

Antidegradation Policies*. Policies that are part of each states water quality standards. These policies are designed to protect water quality and provide a method of assessing activities that might affect the integrity of waterbodies.*

Aquatic ecosystem*. Complex of biotic and abiotic components of natural waters. The aquatic ecosystem is an ecological unit that includes the physical characteristics (such as flow or velocity and depth), the biological community of the water column and benthos, and the chemical characteristics such as dissolved solids, dissolved oxygen, and nutrients. Both living and nonliving components of the aquatic ecosystem interact and influence the properties and status of each component.*

Assimilative capacity. *The amount of contaminant load that can be discharged to a specific waterbody without exceeding water quality standards or criteria. Assimilative capacity is used to define the ability of a waterbody to naturally absorb and use a discharged substance without impairing water quality or harming aquatic life.*

Background levels. *Levels representing the chemical, physical, and biological conditions that would result from natural geomorphological processes such as weathering or dissolution.*

Bacteria. *Single-celled microorganisms. Bacteria of the coliform group are considered the primary indicators of fecal contamination and are often used to assess water quality.*

Bacterial decomposition. *Breakdown by oxidation, or decay, of organic matter by heterotrophic bacteria. Bacteria use the organic carbon in organic matter as the energy source for cell synthesis.*

Bacterial source tracking (BST). A collection of scientific methods used to track sources of fecal contamination.

Best management practices (BMPs). *Methods, measures, or practices determined to be reasonable and cost-effective means for a landowner to meet certain, generally nonpoint source, pollution control needs. BMPs include structural and nonstructural controls and operation and maintenance procedures.*

Bioassessment. Evaluation of the condition of an ecosystem that uses biological surveys and other direct measurements of the resident biota. **(2)**

Biological Integrity. A waterbody's ability to support and maintain a balanced, integrated adaptive assemblage of organisms with species composition, diversity, and functional organization comparable to that of similar natural, or non-impacted habitat.

Biosolids. Biologically treated solids originating from municipal wastewater treatment plants.

Biometric. (Biological Metric) The study of biological phenomena by measurements and statistics.

Box and whisker plot. A graphical representation of the mean, lower quartile, upper quartile, upper limit, lower limit, and outliers of a data set.

Calibration. *The process of adjusting model parameters within physically defensible ranges until the resulting predictions give a best possible good fit to observed data.*

Causal analysis. A process in which data and other information are organized and evaluated using quantitative and logical techniques to determine the likely cause of an observed condition. (2)

Causal association. A correlation or other association between measures or observations of two entities or processes which occurs because of an underlying causal relationship. (2)

Causal mechanism. The process by which a cause induces an effect. (2)

Causal relationship. The relationship between a cause and its effect. (2)

Cause. 1. That which produces an effect (a general definition).

2. A stressor or set of stressors that occur at an intensity, duration and frequency of exposure that results in a change in the ecological condition (a SI-specific definition). (2)

Channel. *A natural stream that conveys water; a ditch or channel excavated for the flow of water.*

Chloride. *An atom of chlorine in solution; an ion bearing a single negative charge.*

Clean Water Act (CWA). *The Clean Water Act (formerly referred to as the Federal Water Pollution Control Act or Federal Water Pollution Control Act Amendments of 1972), Public Law 92-500, as amended by Public Law 96-483 and Public Law 97-117, 33 U.S.C. 1251 et seq. The Clean Water Act (CWA) contains a number of provisions to restore and maintain the quality of the nation's water resources. One of these provisions is Section 303(d), which establishes the TMDL program.*

Coefficient of determination. Represents the proportion of the total sample variability around y that is explained by the linear relationship between *y* and *x*. (In simple linear regression, it may also be computed as the square of the coefficient of correlation *r.)* (3)

Concentration. *Amount of a substance or material in a given unit volume of solution; usually measured in milligrams per liter (mg/L) or parts per million (ppm).*

Concentration-based limit. *A limit based on the relative strength of a pollutant in a waste stream, usually expressed in milligrams per liter (mg/L).*

Concentration-response model. A quantitative (usually statistical) model of the relationship between the concentration of a chemical to which a population or community of organisms is exposed and the frequency or magnitude of a biological response. (2)

Conductivity. An indirect measure of the presence of dissolved substances within water.

Confluence. The point at which a river and its tributary flow together.

Contamination. *The act of polluting or making impure; any indication of chemical, sediment, or biological impurities.*

Continuous discharge. *A discharge that occurs without interruption throughout the operating hours of a facility, except for infrequent shutdowns for maintenance, process changes, or other similar activities.*

Conventional pollutants. *As specified under the Clean Water Act, conventional contaminants include suspended solids, coliform bacteria, high biochemical oxygen demand, pH, and oil and grease.*

Conveyance. A measure of the of the water carrying capacity of a channel section. It is directly proportional to the discharge in the channel section.

Cost-share program. *A program that allocates project funds to pay a percentage of the cost of constructing or implementing a best management practice. The remainder of the costs is paid by the producer(s).*

Cross-sectional area. *Wet area of a waterbody normal to the longitudinal component of the flow.*

Critical condition. *The critical condition can be thought of as the "worst case" scenario of environmental conditions in the waterbody in which the loading expressed in the TMDL for the pollutant of concern will continue to meet water quality standards. Critical conditions are the combination of environmental factors (e.g., flow, temperature, etc.) that results in attaining and maintaining the water quality criterion and has an acceptably low frequency of occurrence.*

Decay. *The gradual decrease in the amount of a given substance in a given system due to various sink processes including chemical and biological transformation, dissipation to other environmental media, or deposition into storage areas.*

Decomposition. *Metabolic breakdown of organic materials; the formation of by-products of decomposition releases energy and simple organic and inorganic compounds. See also Respiration.*

Designated uses. *Those uses specified in water quality standards for each waterbody or segment whether or not they are being attained.*

Deterministic model. *A model that does not include built-in variability: same input will always result in the same output.*

Dilution. *The addition of some quantity of less-concentrated liquid (water) that results in a decrease in the original concentration.*

Direct runoff. *Water that flows over the ground surface or through the ground directly into streams, rivers, and lakes.*

Discharge. *Flow of surface water in a stream or canal, or the outflow of groundwater from a flowing artesian well, ditch, or spring. Can also apply to discharge of liquid effluent from a facility or to chemical emissions into the air through designated venting mechanisms.*

Discharge Monitoring Report (DMR). *Report of effluent characteristics submitted by a municipal or industrial facility that has been granted an NPDES discharge permit.*

Discharge permits (under NPDES). *A permit issued by the U.S. EPA or a state regulatory agency that sets specific limits on the type and amount of pollutants that a municipality or industry can discharge to receiving water; it also includes a compliance schedule for achieving those limits. The permit process was established under the National Pollutant Discharge Elimination System, under provisions of the Federal Clean Water Act.*

Dispersion. *The spreading of chemical or biological constituents, including pollutants, in various directions at varying velocities depending on the differential in-stream flow characteristics.*

Diurnal. *Actions or processes that have a period or a cycle of approximately one tidal-day or are completed within a 24-hour period and that recur every 24 hours. Also, the occurrence of an activity/process during the day rather than the night.*

DNA. Deoxyribonucleic acid. The genetic material of cells and some viruses.

Domestic wastewater. *Also called sanitary wastewater, consists of wastewater discharged from residences and from commercial, institutional, and similar facilities.*

Drainage basin. *A part of a land area enclosed by a topographic divide from which direct surface runoff from precipitation normally drains by gravity into a receiving water. Also referred to as a watershed, river basin, or hydrologic unit.*

Dynamic model. *A mathematical formulation describing and simulating the physical behavior of a system or a process and its temporal variability.*

Dynamic simulation. *Modeling of the behavior of physical, chemical, and/or biological phenomena and their variations over time.*

Ecoregion. A region defined in part by its shared characteristics. These include meteorological factors, elevation, plant and animal speciation, landscape position, and soils.

Ecosystem. *An interactive system that includes the organisms of a natural community association together with their abiotic physical, chemical, and geochemical environment.*

Effluent. *Municipal sewage or industrial liquid waste (untreated, partially treated, or completely treated) that flows out of a treatment plant, septic system, pipe, etc.*

Effluent guidelines. *The national effluent guidelines and standards specify the achievable effluent pollutant reduction that is attainable based upon the performance of treatment technologies employed within an industrial category. The National Effluent Guidelines Program was established with a phased approach whereby industry would first be required to meet interim limitations based on best practicable control technology currently available for existing sources (BPT). The second level of effluent limitations to be attained by industry was referred to as best available technology economically achievable (BAT), which was established primarily for the control of toxic pollutants.*

Effluent limitation. *Restrictions established by a state or EPA on quantities, rates, and concentrations in pollutant discharges.*

Empirical model. *Use of statistical techniques to discern patterns or relationships underlying observed or measured data for large sample sets. Does not account for physical dynamics of waterbodies.*

Endpoint. *An endpoint (or indicator/target) is a characteristic of an ecosystem that may be affected by exposure to a stressor. Assessment endpoints and measurement endpoints are two distinct types of endpoints commonly used by resource managers. An assessment* *endpoint is the formal expression of a valued environmental characteristic and should have societal relevance (an indicator). A measurement endpoint is the expression of an observed or measured response to a stress or disturbance. It is a measurable environmental characteristic that is related to the valued environmental characteristic chosen as the assessment endpoint. The numeric criteria that are part of traditional water quality standards are good examples of measurement endpoints (targets).*

Enhancement. *In the context of restoration ecology, any improvement of a structural or functional attribute.*

Erosion. The detachment and transport of soil particles by water and wind. Sediment resulting from soil erosion represents the single largest source of nonpoint pollution in the United States.

Eutrophication. The process of enrichment of water bodies by nutrients. Waters receiving excessive nutrients may become eutrophic, are often undesirable for recreation, and may not support normal fish populations.

Evapotranspiration. The combined effects of evaporation and transpiration on the water balance. Evaporation is water loss into the atmosphere from soil and water surfaces. Transpiration is water loss into the atmosphere as part of the life cycle of plants.

Existing use. *Use actually attained in the waterbody on or after November 28, 1975, whether or not it is included in the water quality standards (40 CFR 131.3).*

Fate of pollutants. *Physical, chemical, and biological transformation in the nature and changes of the amount of a pollutant in an environmental system. Transformation processes are pollutant-specific. Because they have comparable kinetics, different formulations for each pollutant are not required.*

Fecal Coliform. Indicator organisms (organisms indicating presence of pathogens) associated with the digestive tract.

Feedlot. *A confined area for the controlled feeding of animals. Tends to concentrate large amounts of animal waste that cannot be absorbed by the soil and, hence, may be carried to nearby streams or lakes by rainfall runoff.*

First-order kinetics. *The type of relationship describing a dynamic reaction in which the rate of transformation of a pollutant is proportional to the amount of that pollutant in the environmental system.*

Flux. *Movement and transport of mass of any water quality constituent over a given period of time. Units of mass flux are mass per unit time.*

General Standard. A narrative standard that ensures the general health of state waters. All state waters, including wetlands, shall be free from substances attributable to sewage, industrial waste, or other waste in concentrations, amounts, or combinations which contravene established standards or interfere directly or indirectly with designated uses of such water or which are inimical or harmful to human, animal, plant, or aquatic life (9VAC25-260-20). (4)

Geometric mean. A measure of the central tendency of a data set that minimizes the effects of extreme values.

GIS. Geographic Information System. A system of hardware, software, data, people, organizations and institutional arrangements for collecting, storing, analyzing and disseminating information about areas of the earth. (Dueker and Kjerne, 1989)

Ground water. *The supply of fresh water found beneath the earths surface, usually in aquifers, which supply wells and springs. Because ground water is a major source of drinking water, there is growing concern over contamination from leaching agricultural or industrial pollutants and leaking underground storage tanks.*

HSPF. Hydrological Simulation Program – Fortran. A computer simulation tool used to mathematically model nonpoint source pollution sources and movement of pollutants in a watershed.

Hydrograph*. A graph showing variation of stage (depth) or discharge in a stream over a period of time.*

Hydrologic cycle. *The circuit of water movement from the atmosphere to the earth and its return to the atmosphere through various stages or processes, such as precipitation, interception, runoff, infiltration, storage, evaporation, and transpiration.*

Hydrology. *The study of the distribution, properties, and effects of water on the earth's surface, in the soil and underlying rocks, and in the atmosphere.*

Hyetograph. *Graph of rainfall rate versus time during a storm event.*

IMPLND. An impervious land segment in HSPF. It is used to model land covered by impervious materials, such as pavement.

Indicator. *A measurable quantity that can be used to evaluate the relationship between pollutant sources and their impact on water quality.*

Indicator organism. *An organism used to indicate the potential presence of other (usually pathogenic) organisms. Indicator organisms are usually associated with the other organisms, but are usually more easily sampled and measured.*

Indirect causation. The induction of effects through a series of cause-effect relationships, so that the impaired resource may not even be exposed to the initial cause. (2)

Indirect effects. Changes in a resource that is due to a series of cause-effect relationships rather than to direct exposure to a contaminant or other stressor. (2)

Infiltration capacity. *The capacity of a soil to allow water to infiltrate into or through it during a storm.*

In situ. *In place; in situ measurements consist of measurements of components or processes in a full-scale system or a field, rather than in a laboratory.*

Interflow. Runoff that travels just below the surface of the soil.

Isolate. An inbreeding biological population that is isolated from similar populations by physical or other means.

Leachate. *Water that collects contaminants as it trickles through wastes, pesticides, or fertilizers. Leaching can occur in farming areas, feedlots, and landfills and can result in hazardous substances entering surface water, ground water, or soil.*

Limits (upper and lower). The lower limit equals the lower quartile – 1.5x(upper quartile – lower quartile), and the upper limit equals the upper quartile + 1.5x(upper quartile – lower quartile). Values outside these limits are referred to as outliers.

Loading, Load, Loading rate. *The total amount of material (pollutants) entering the system from one or multiple sources; measured as a rate in weight per unit time.*

Load allocation (LA). *The portion of a receiving waters loading capacity attributed either to one of its existing or future nonpoint sources of pollution or to natural background sources. Load allocations are best estimates of the loading, which can range from reasonably accurate estimates to gross allotments, depending on the availability of data and appropriate techniques for predicting the loading. Wherever possible, natural and nonpoint source loads should be distinguished (40 CFR 130.2(g)).*

Loading capacity (LC). *The greatest amount of loading a water can receive without violating water quality standards.*

Margin of safety (MOS). *A required component of the TMDL that accounts for the uncertainty about the relationship between the pollutant loads and the quality of the receiving waterbody (CWA Section 303(d)(1)(C)). The MOS is normally incorporated into the conservative assumptions used to develop TMDLs (generally within the calculations or models) and approved by EPA either individually or in state/EPA agreements. If the MOS needs to be larger than that which is allowed through the conservative assumptions, additional MOS can be added as a separate component of the TMDL (in this case, quantitatively, a TMDL = LC = WLA + LA + MOS).*

Mass balance. *An equation that accounts for the flux of mass going into a defined area and the flux of mass leaving the defined area. The flux in must equal the flux out.*

Mass loading. *The quantity of a pollutant transported to a waterbody.*

Mathematical model. *A system of mathematical expressions that describe the spatial and temporal distribution of water quality constituents resulting from fluid transport and the* *one or more individual processes and interactions within some prototype aquatic ecosystem. A mathematical water quality model is used as the basis for waste load allocation evaluations.*

Mean. The sum of the values in a data set divided by the number of values in the data set.

Metrics. Indices or parameters used to measure some aspect or characteristic of a water body's biological integrity. The metric changes in some predictable way with changes in water quality or habitat condition.

MGD. Million gallons per day. A unit of water flow, whether discharge or withdraw.

Mitigation. *Actions taken to avoid, reduce, or compensate for the effects of environmental damage. Among the broad spectrum of possible actions are those that restore, enhance, create, or replace damaged ecosystems.*

Model. Mathematical representation of hydrologic and water quality processes. Effects of land use, slope, soil characteristics, and management practices are included.

Monitoring. *Periodic or continuous surveillance or testing to determine the level of compliance with statutory requirements and/or pollutant levels in various media or in humans, plants, and animals.*

Mood's Median Test. A nonparametric (distribution-free) test used to test the equality of medians from two or more populations.

Multivariate Regression. A functional relationship between 1 dependent variable and multiple independent variables that are often empirically determined from data and are used especially to predict values of one variable when given values of the others.

Narrative criteria. *Nonquantitative guidelines that describe the desired water quality goals.*

National Pollutant Discharge Elimination System (NPDES). *The national program for issuing, modifying, revoking and re-issuing, terminating, monitoring, and enforcing permits, and imposing and enforcing pretreatment requirements, under sections 307, 402, 318, and 405 of the Clean Water Act.*

Natural waters. *Flowing water within a physical system that has developed without human intervention, in which natural processes continue to take place.*

Nonpoint source. *Pollution that originates from multiple sources over a relatively large area. Nonpoint sources can be divided into source activities related to either land or water use including failing septic tanks, improper animal-keeping practices, forest practices, and urban and rural runoff.*

Numeric targets. *A measurable value determined for the pollutant of concern, which, if achieved, is expected to result in the attainment of water quality standards in the listed waterbody.*

Numerical model. Model that approximates a solution of governing partial differential equations, which describe a natural process. The approximation uses a numerical discretization of the space and time components of the system or process.

Nutrient. An element or compound essential to life, including carbon, oxygen, nitrogen, phosphorus, and many others: as a pollutant, any element or compound, such as phosphorus or nitrogen, that in excessive amounts contributes to abnormally high growth of algae, reducing light and oxygen in aquatic ecosystems.

Organic matter. *The organic fraction that includes plant and animal residue at various stages of decomposition, cells and tissues of soil organisms, and substances synthesized by the soil population. Commonly determined as the amount of organic material contained in a soil or water sample.*

Parameter. A numerical descriptive measure of a population. Since it is based on the observations of the population, its value is almost always unknown.

Peak runoff. *The highest value of the stage or discharge attained by a flood or storm event; also referred to as flood peak or peak discharge.*

PERLND. A pervious land segment in HSPF. It is used to model a particular land use segment within a subwatershed (e.g. pasture, urban land, or crop land).

Permit. *An authorization, license, or equivalent control document issued by EPA or an approved federal, state, or local agency to implement the requirements of an environmental regulation; e.g., a permit to operate a wastewater treatment plant or to operate a facility that may generate harmful emissions.*

Permit Compliance System (PCS). *Computerized management information system that contains data on NPDES permit-holding facilities. PCS keeps extensive records on more than 65,000 active water-discharge permits on sites located throughout the nation. PCS tracks permit, compliance, and enforcement status of NPDES facilities.*

Phased/staged approach. *Under the phased approach to TMDL development, load allocations and wasteload allocations are calculated using the best available data and information recognizing the need for additional monitoring data to accurately characterize sources and loadings. The phased approach is typically employed when nonpoint sources dominate. It provides for the implementation of load reduction strategies while collecting additional data.*

Point source. *Pollutant loads discharged at a specific location from pipes, outfalls, and conveyance channels from either municipal wastewater treatment plants or industrial waste treatment facilities. Point sources can also include pollutant loads contributed by tributaries to the main receiving water stream or river.*

Pollutant. *Dredged spoil, solid waste, incinerator residue, sewage, garbage, sewage sludge, munitions, chemical wastes, biological materials, radioactive materials, heat, wrecked or discarded equipment, rock, sand, cellar dirt, and industrial, municipal, and agricultural waste discharged into water. (CWA section 502(6)).*

Pollution. *Generally, the presence of matter or energy whose nature, location, or quantity produces undesired environmental effects. Under the Clean Water Act, for example, the term is defined as the man-made or man-induced alteration of the physical, biological, chemical, and radiological integrity of water.*

Postaudit. *A subsequent examination and verification of a model's predictive performance following implementation of an environmental control program.*

Privately owned treatment works. *Any device or system that is (a) used to treat wastes from any facility whose operator is not the operator of the treatment works and (b) not a publicly owned treatment works.*

Public comment period. *The time allowed for the public to express its views and concerns regarding action by EPA or states (e.g., a* Federal Register *notice of a proposed rule-making, a public notice of a draft permit, or a Notice of Intent to Deny).*

Publicly owned treatment works (POTW). *Any device or system used in the treatment (including recycling and reclamation) of municipal sewage or industrial wastes of a liquid nature that is owned by a state or municipality. This definition includes sewers, pipes, or other conveyances only if they convey wastewater to a POTW providing treatment.*

Quartile. The 25th, 50th, and 75th percentiles of a data set. A percentile (p) of a data set ordered by magnitude is the value that has at most p% of the measurements in the data set below it, and (100-p)% above it. The 50th quartile is also known as the median. The 25th and 75th quartiles are referred to as the lower and upper quartiles, respectively.

Raw sewage*. Untreated municipal sewage.*

Reach. Segment of a stream or river.

Receiving waters. *Creeks, streams, rivers, lakes, estuaries, ground water formations, or other bodies of water into which surface water and/or treated or untreated waste are discharged, either naturally or in man-made systems.*

Reference Conditions. The chemical, physical, or biological quality or condition exhibited at either a single site or an aggregation of sites that are representative of non-impaired conditions for a watershed of a certain size, land use distribution, and other related characteristics. Reference conditions are used to describe reference sites.

Reserve capacity. *Pollutant loading rate set aside in determining stream waste load allocation, accounting for uncertainty and future growth.*

Residence time. *Length of time that a pollutant remains within a section of a stream or river. The residence time is determined by the streamflow and the volume of the river reach or the average stream velocity and the length of the river reach.*

Restoration. *Return of an ecosystem to a close approximation of its presumed condition prior to disturbance.*

Riparian areas. *Areas bordering streams, lakes, rivers, and other watercourses. These areas have high water tables and support plants that require saturated soils during all or part of the year. Riparian areas include both wetland and upland zones.*

Riparian zone. *The border or banks of a stream. Although this term is sometimes used interchangeably with floodplain, the riparian zone is generally regarded as relatively narrow compared to a floodplain. The duration of flooding is generally much shorter, and the timing less predictable, in a riparian zone than in a river floodplain.*

Roughness coefficient. *A factor in velocity and discharge formulas representing the effects of channel roughness on energy losses in flowing water. Manning's "n" is a commonly used roughness coefficient.*

Runoff. *That part of precipitation, snowmelt, or irrigation water that runs off the land into streams or other surface water. It can carry pollutants from the air and land into receiving waters.*

Seasonal Kendall test. A statistical tool used to test for trends in data, which is unaffected by seasonal cycles.

Sediment. In the context of water quality, soil particles, sand, and minerals dislodged from the land and deposited into aquate systems as a result of erosion.

Septic system. *An on-site system designed to treat and dispose of domestic sewage. A typical septic system consists of a tank that receives waste from a residence or business and a drain field or subsurface absorption system consisting of a series of percolation lines for the disposal of the liquid effluent. Solids (sludge) that remain after decomposition by bacteria in the tank must be pumped out periodically.*

Sewer*. A channel or conduit that carries wastewater and storm water runoff from the source to a treatment plant or receiving stream. Sanitary sewers carry household, industrial, and commercial waste. Storm sewers carry runoff from rain or snow. Combined sewers handle both.*

Simulation. *The use of mathematical models to approximate the observed behavior of a natural water system in response to a specific known set of input and forcing conditions. Models that have been validated, or verified, are then used to predict the response of a natural water system to changes in the input or forcing conditions.*

Slope. *The degree of inclination to the horizontal. Usually expressed as a ratio, such as 1:25 or 1 on 25, indicating one unit vertical rise in 25 units of horizontal distance, or in a decimal fraction (0.04), degrees (2 degrees 18 minutes), or percent (4 percent).*

Source. An origination point, area, or entity that releases or emits a stressor. A source can alter the normal intensity, frequency, or duration of a natural attribute, whereby the attribute then becomes a stressor. (2)

Spatial segmentation. *A numerical discretization of the spatial component of a system into one or more dimensions; forms the basis for application of numerical simulation models.*

Staged Implementation. A process that allows for the evaluation of the adequacy of the TMDL in achieving the water quality standard. As stream monitoring continues to occur, staged or phased implementation allows for water quality improvements to be recorded as they are being achieved. It also provides a measure of quality control, and it helps to ensure that the most cost-effective practices are implemented first.

Stakeholder. Any person with a vested interest in the TMDL development.

Standard. In reference to water quality (*e.g*. 200 cfu/100 ml geometric mean limit).

Standard deviation. A measure of the variability of a data set. The positive square root of the variance of a set of measurements.

Standard error. The standard deviation of a distribution of a sample statistic, esp. when the mean is used as the statistic.

Statistical significance. An indication that the differences being observed are not due to random error. The p-value indicates the probability that the differences are due to random error (*i.e*. a low p-value indicates statistical significance).

Steady-state model. *Mathematical model of fate and transport that uses constant values of input variables to predict constant values of receiving water quality concentrations. Model variables are treated as not changing with respect to time.*

Stepwise regression. All possible one-variable models of the form $E(y) = B_0 + B_1 x_1$ are fit and the "best" x_1 is selected based on the *t*-test for B_1. Next, two-variable models of the form $E(y) = B_0 + B_1 x_1 + B_2 x_i$ are fit (where x_i is the variable selected in the first step): the "second best" x_i is selected based on the test for B_2. The process continues in this fashion until no more "important" *x*'s can be added to the model. (3)

Storm runoff. *Storm water runoff, snowmelt runoff, and surface runoff and drainage; rainfall that does not evaporate or infiltrate the ground because of impervious land surfaces or a soil infiltration rate lower than rainfall intensity, but instead flows onto adjacent land or into waterbodies or is routed into a drain or sewer system.*

Streamflow. *Discharge that occurs in a natural channel. Although the term "discharge" can be applied to the flow of a canal, the word "streamflow" uniquely describes the discharge in a surface stream course. The term "streamflow" is more general than "runoff" since streamflow may be applied to discharge whether or not it is affected by diversion or regulation.*

Stream Reach. A straight portion of a stream.

Stream restoration. *Various techniques used to replicate the hydrological, morphological, and ecological features that have been lost in a stream because of urbanization, farming, or other disturbance.*

Surface area. *The area of the surface of a waterbody; best measured by planimetry or the use of a geographic information system.*

Surface runoff. *Precipitation, snowmelt, or irrigation water in excess of what can infiltrate the soil surface and be stored in small surface depressions; a major transporter of nonpoint source pollutants.*

Surface water. *All water naturally open to the atmosphere (rivers, lakes, reservoirs, ponds, streams, impoundments, seas, estuaries, etc.) and all springs, wells, or other collectors directly influenced by surface water.*

Technology-based standards. *Effluent limitations applicable to direct and indirect sources that are developed on a category-by-category basis using statutory factors, not including water quality effects.*

Timestep. An increment of time in modeling terms. The smallest unit of time used in a mathematical simulation model (*e.g.* 15-minutes, 1-hour, 1-day).

Topography. *The physical features of a geographic surface area including relative elevations and the positions of natural and man-made features.*

Total Maximum Daily Load (TMDL). *The sum of the individual wasteload allocations (WLAs) for point sources, load allocations (LAs) for nonpoint sources and natural background, plus a margin of safety (MOS). TMDLs can be expressed in terms of mass per time, toxicity, or other appropriate measures that relate to a state's water quality standard.*

TMDL Implementation Plan. A document required by Virginia statute detailing the suite of pollution control measures needed to remediate an impaired stream segment. The plans are also required to include a schedule of actions, costs, and monitoring. Once implemented, the plan should result in the previously impaired water meeting water quality standards and achieving a "fully supporting" use support status.

Transport of pollutants (in water). *Transport of pollutants in water involves two main processes: (1) advection, resulting from the flow of water, and (2) dispersion, or transport due to turbulence in the water.*

TRC. Total Residual Chlorine. A measure of the effectiveness of chlorinating treated waste water effluent.

Tributary. *A lower order-stream compared to a receiving waterbody. "Tributary to" indicates the largest stream into which the reported stream or tributary flows.*

Urban Runoff. Surface runoff originating from an urban drainage area including streets, parking lots, and rooftops.

Validation (of a model). *Process of determining how well the mathematical model's computer representation describes the actual behavior of the physical processes under investigation. A validated model will have also been tested to ascertain whether it accurately and correctly solves the equations being used to define the system simulation.*

Variance. A measure of the variability of a data set. The sum of the squared deviations (observation – mean) divided by (number of observations) – 1.

VADACS. Virginia Department of Agriculture and Consumer Services.

VADCR. Virginia Department of Conservation and Recreation.

VADEQ. Virginia Department of Environmental Quality.

VDH. Virginia Department of Health.

Wasteload allocation (WLA). *The portion of a receiving waters' loading capacity that is allocated to one of its existing or future point sources of pollution. WLAs constitute a type of water quality-based effluent limitation (40 CFR 130.2(h)).*

Wastewater. *Usually refers to effluent from a sewage treatment plant. See also Domestic wastewater.*

Wastewater treatment. *Chemical, biological, and mechanical procedures applied to an industrial or municipal discharge or to any other sources of contaminated water to remove, reduce, or neutralize contaminants.*

Water quality. *The biological, chemical, and physical conditions of a waterbody. It is a measure of a waterbody's ability to support beneficial uses.*

Water quality-based effluent limitations (WQBEL). *Effluent limitations applied to dischargers when technology-based limitations alone would cause violations of water quality standards. Usually WQBELs are applied to discharges into small streams.*

Water quality-based permit*. A permit with an effluent limit more stringent than one based on technology performance. Such limits might be necessary to protect the designated use of receiving waters (e.g., recreation, irrigation, industry, or water supply).*

Water quality criteria. *Levels of water quality expected to render a body of water suitable for its designated use, composed of numeric and narrative criteria. Numeric criteria are scientifically derived ambient concentrations developed by EPA or states for various pollutants of concern to protect human health and aquatic life. Narrative criteria are statements that describe the desired water quality goal. Criteria are based on specific levels of pollutants that would make the water harmful if used for drinking, swimming, farming, fish production, or industrial processes.*

Water quality standard. *Law or regulation that consists of the beneficial designated use or uses of a waterbody, the numeric and narrative water quality criteria that are necessary to protect the use or uses of that particular waterbody, and an antidegradation statement.*

Watershed. *A drainage area or basin in which all land and water areas drain or flow toward a central collector such as a stream, river, or lake at a lower elevation.*

WQIA. Water Quality Improvement Act.

APPENDIX A

Frequency plots for fecal coliform and E.coli at VADEQ monitoring stations used in water quality calibration and validation

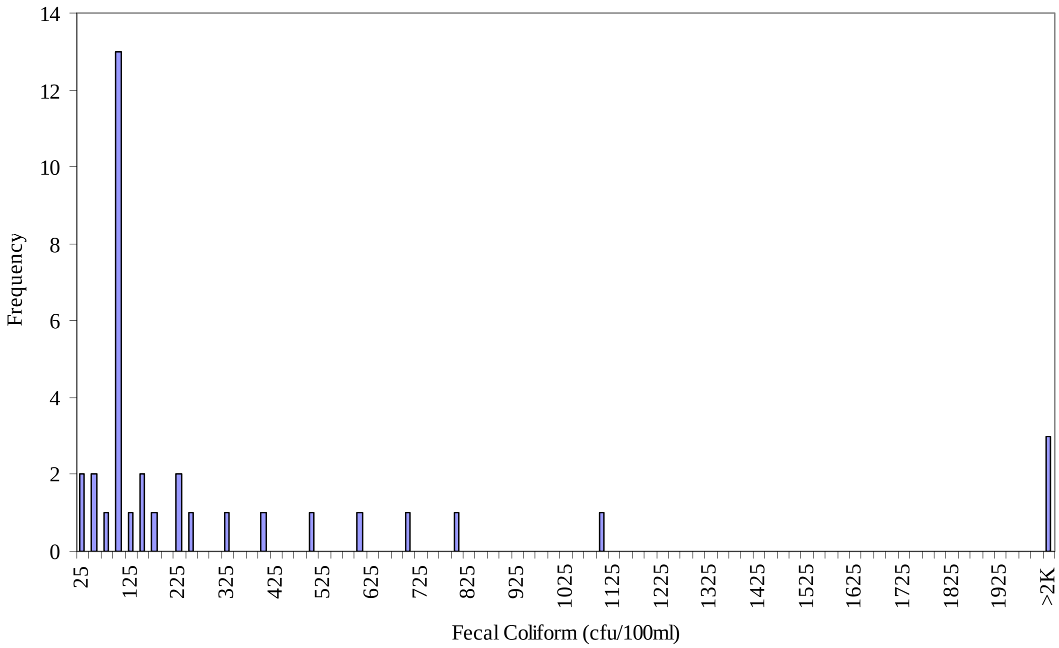

Figure A.1 **Frequency analysis of *fecal coliform* concentrations at station 2-BYR003.35 in the Byrd Creek watershed for the period January 1980 to December 2005.**

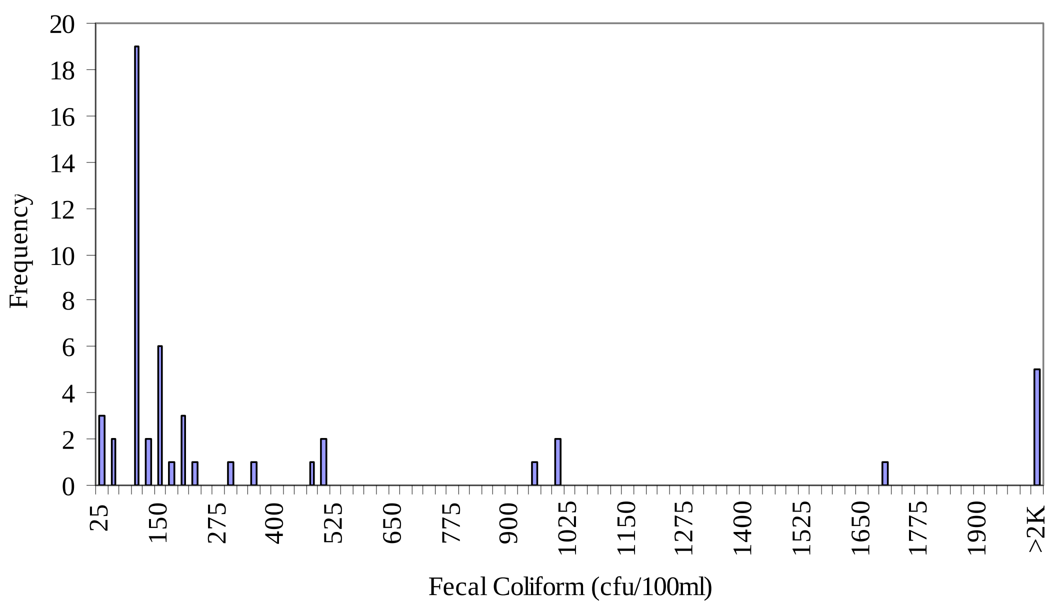

Figure A.2 **Frequency analysis of fecal coliform concentrations at station 2-BLG002.60 in the Big Lickinghole Creek watershed for the period January 1980 to December 2005.**

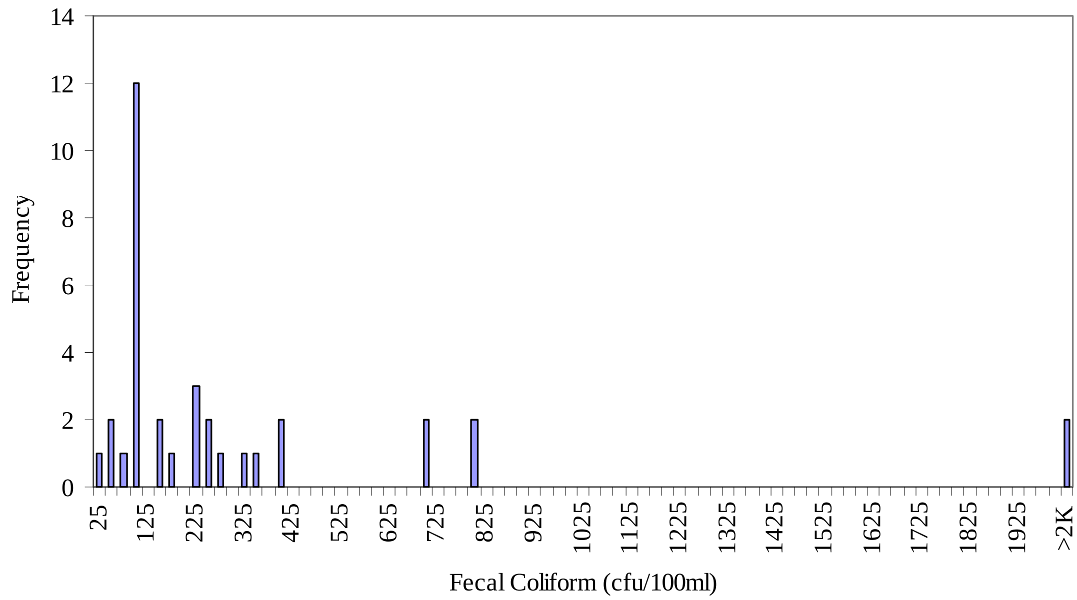

Figure A.3 Frequency analysis of *fecal coliform* concentrations at station 2-BDC000.79 in the Beaverdam Creek watershed for the period January 1980 to December 2005.

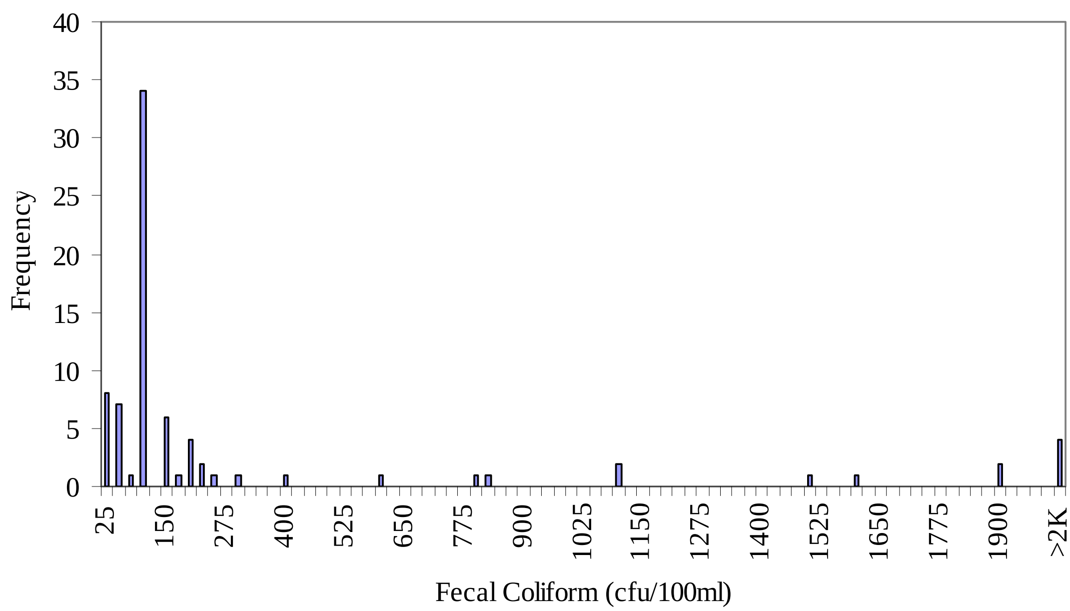

Figure A.4 Frequency analysis of *fecal coliform* concentrations at station 2-FIN000.81 in the Fine Creek watershed for the period January 1980 to December 2005.

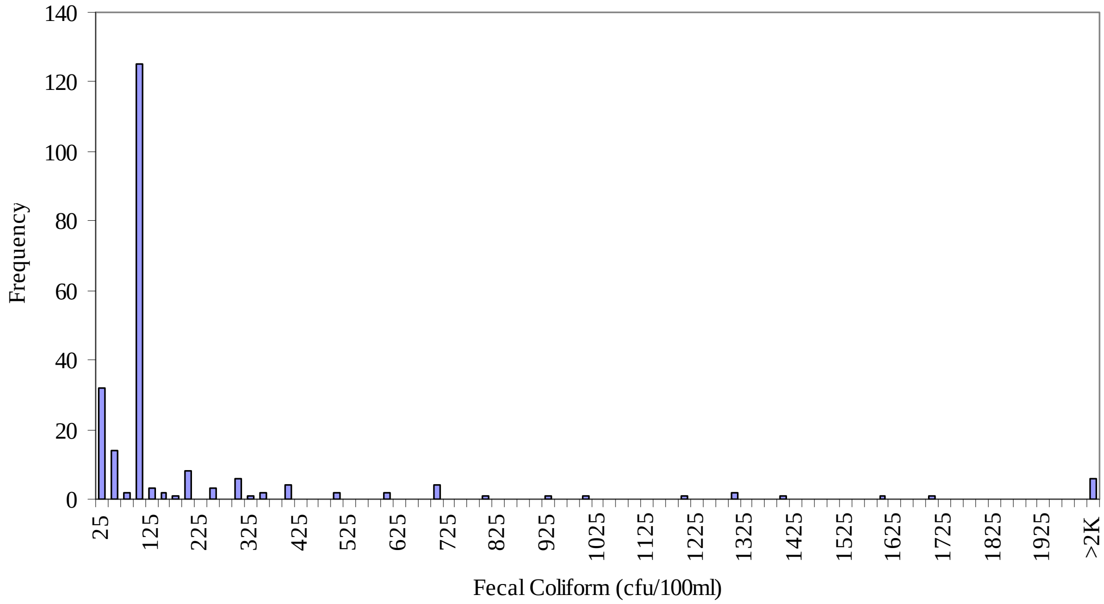

Figure A.5 Frequency analysis of *fecal coliform* concentrations at station 2-JMS157.28 in the James River watershed for the period January 1980 to December 2005.

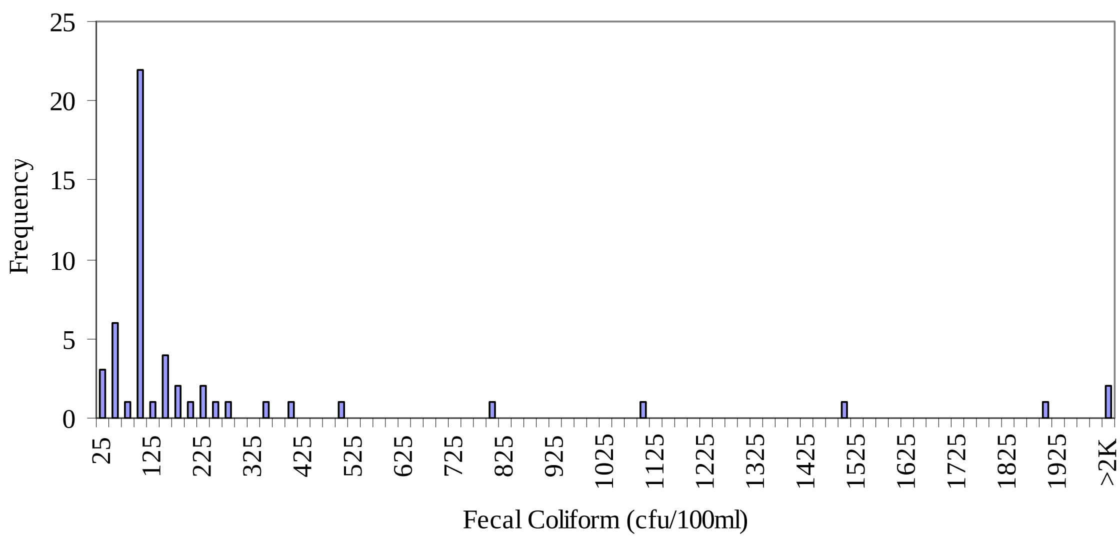

Figure A.6 Frequency analysis of *fecal coliform* concentrations at station 2-BDC003.00 in the Deep Creek watershed for the period January 1980 to December 2005.

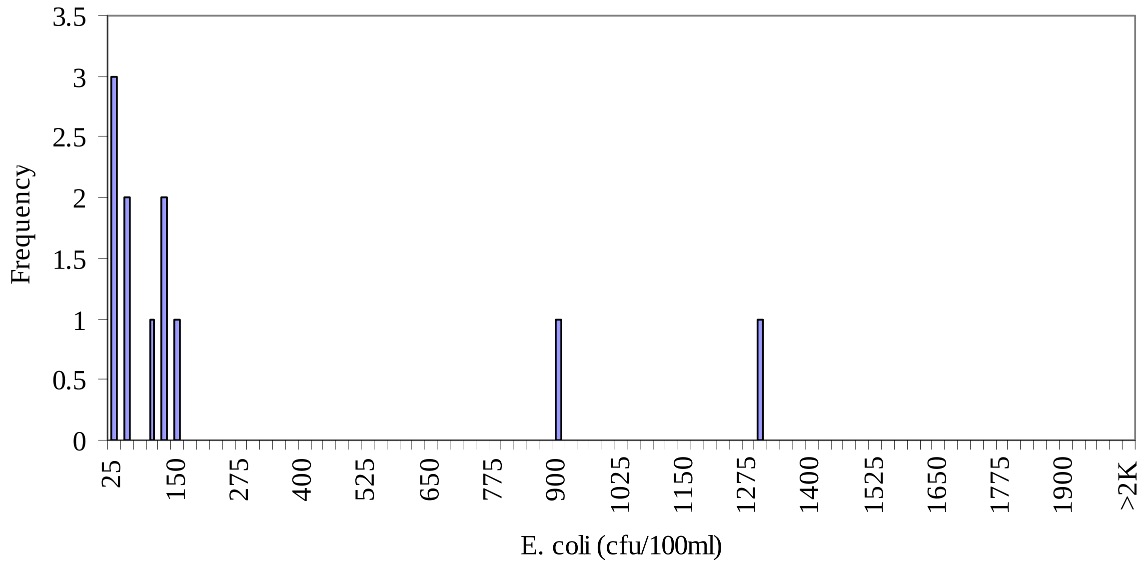

Figure A.7 **Frequency analysis of *E. coli* concentrations at station 2-BLG002.60in the Big Lickinghole Creek watershed for the period January 1980 to December 2005.**

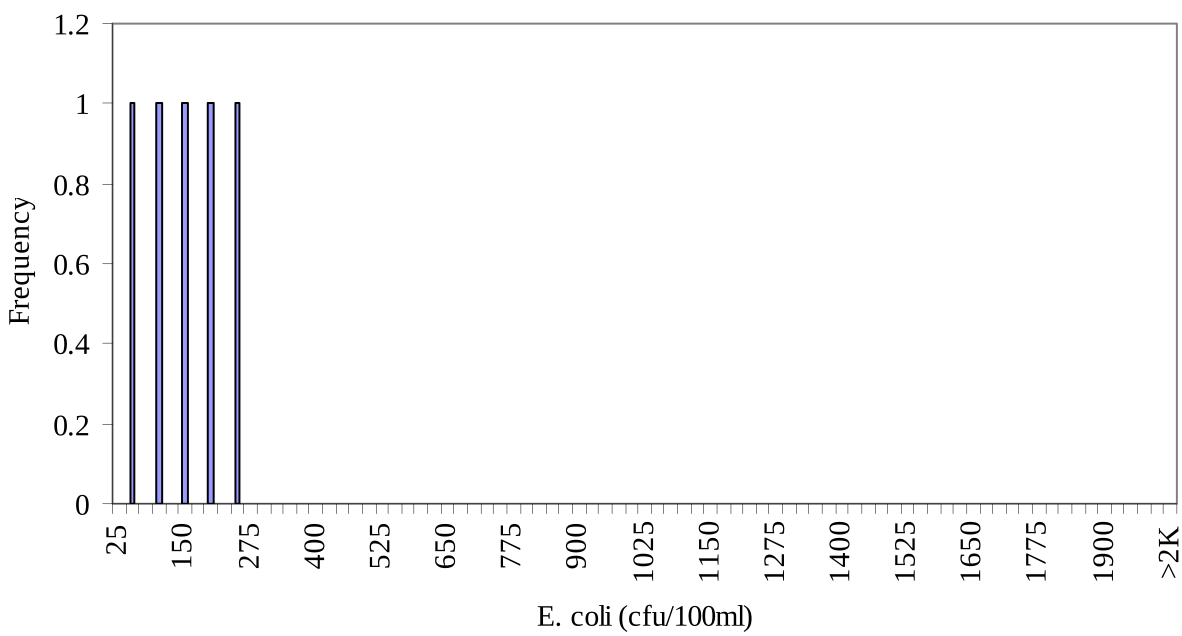

Figure A.8 **Frequency analysis of *E. coli* concentrations at station 2-BDC000.79 in the Beaverdam Creek watershed for the period January 1980 to December 2005.**

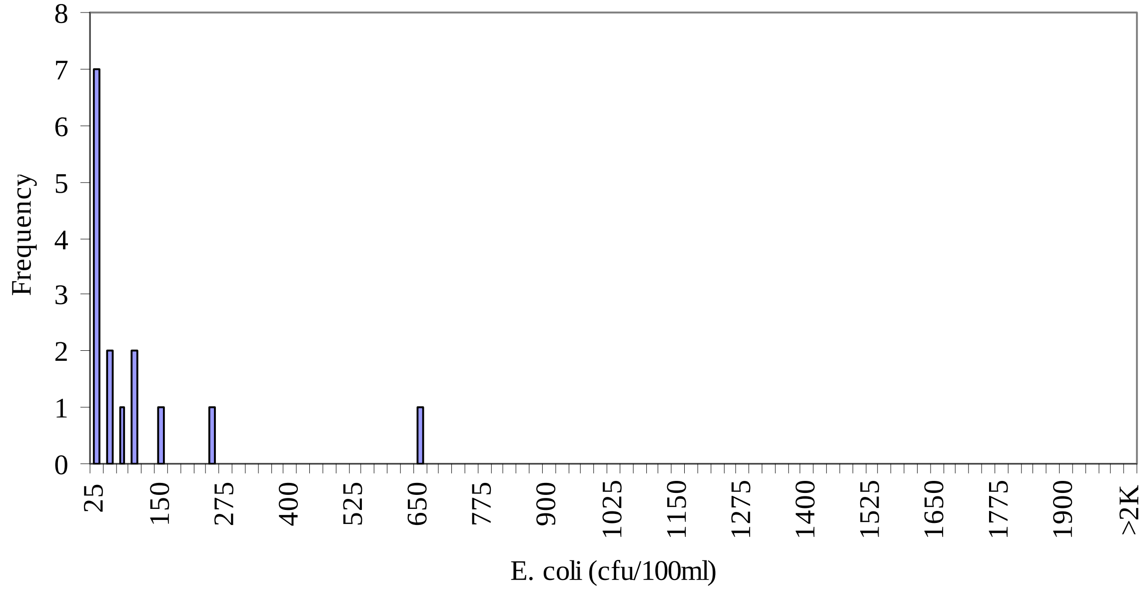

Figure A.9 **Frequency analysis of *E. coli* concentrations at station 2-FIN000.81 in the Fine Creek watershed for the period January 1980 to December 2005.**

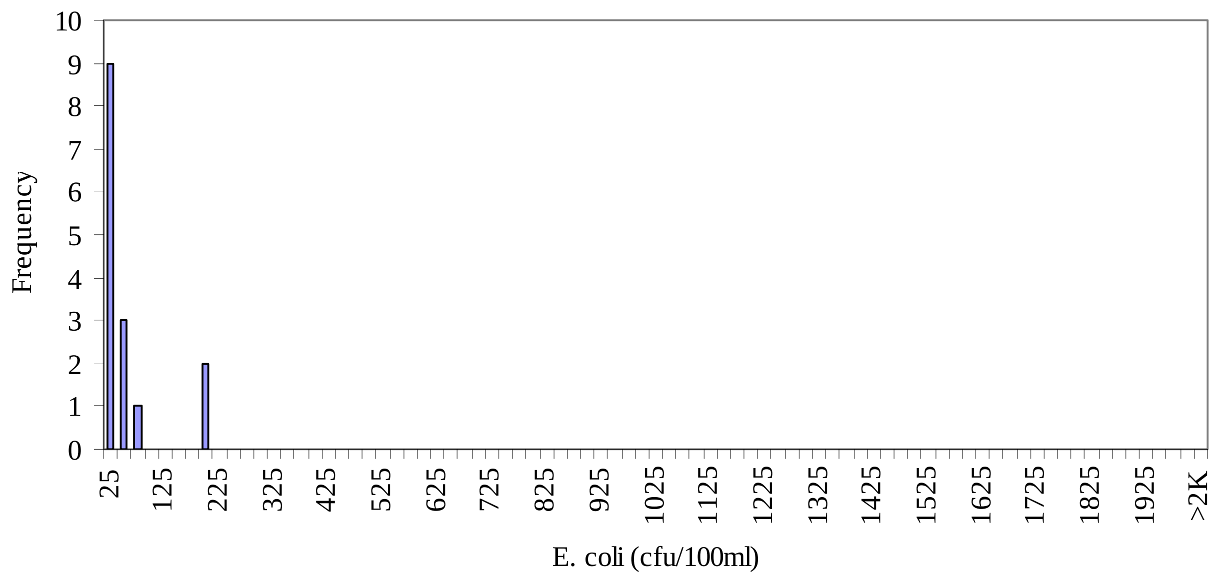

Figure A.10 **Frequency analysis of *E. coli* concentrations at station 2-BDC003.00 in the Deep Creek for the period January 1980 to December 2005.**

APPENDIX B

Current conditions fecal coliform

Loads by Source, Land use, and sub-water shed

Table B.1 **Current conditions of land applied fecal coliform load for the Byrd Creek segment by land use (subwatersheds 10,11,12,13,20).**

Land-use	January	February	March	April	May	June	July	August	September	October	November	December	Annual Total Loads (cfu/yr)
Barren	3.96E+10	3.58E+10	3.96E+10	3.83E+10	3.96E+10	3.83E+10	3.96E+10	3.96E+10	3.83E+10	3.96E+10	3.83E+10	3.96E+10	4.66E+11
Forest	4.25E+13	3.84E+13	4.25E+13	4.12E+13	4.25E+13	4.12E+13	4.25E+13	4.25E+13	4.12E+13	4.25E+13	4.12E+13	4.25E+13	5.01E+14
Livestock Access	3.63E+12	3.28E+12	4.99E+12	6.58E+12	6.80E+12	7.90E+12	8.16E+12	8.16E+12	6.58E+12	4.99E+12	4.83E+12	3.63E+12	6.95E+13
Low Dens. Res.	1.00E+13	8.93E+12	9.62E+12	9.18E+12	9.35E+12	8.91E+12	8.94E+12	8.94E+12	8.65E+12	8.81E+12	8.65E+12	9.48E+12	1.09E+14
Pasture	1.95E+14	1.77E+14	1.93E+14	1.85E+14	1.91E+14	2.11E+14	2.17E+14	2.17E+14	1.85E+14	1.93E+14	1.87E+14	1.95E+14	2.35E+15
Row Crop	2.82E+13	2.82E+13	2.81E+14	2.81E+14	7.04E+13	1.30E+11	1.34E+11	1.34E+11	2.95E+14	2.81E+14	2.82E+13	2.82E+13	1.32E+15
Wetlands	5.51E+12	4.98E+12	5.51E+12	5.33E+12	5.51E+12	5.33E+12	5.51E+12	5.51E+12	5.33E+12	5.51E+12	5.33E+12	5.51E+12	6.49E+13

Table B.2 Current conditions of land applied fecal coliform loads for Big & Little Lickinghole impairment by land use (subwatersheds 14,15,16).

Land-use	January	February	March	April	May	June	July	August	September	October	November	December	Annual Total Loads (cfu/yr)
Barren	6.65E+10	6.01E+10	6.65E+10	6.44E+10	6.65E+10	6.44E+10	6.65E+10	6.65E+10	6.44E+10	6.65E+10	6.44E+10	6.65E+10	7.84E+11
Forest	3.44E+13	3.11E+13	3.44E+13	3.33E+13	3.44E+13	3.33E+13	3.44E+13	3.44E+13	3.33E+13	3.44E+13	3.33E+13	3.44E+13	4.05E+14
Livestock Access	1.17E+12	1.06E+12	1.58E+12	2.05E+12	2.12E+12	2.45E+12	2.53E+12	2.53E+12	2.05E+12	1.58E+12	1.53E+12	1.17E+12	2.18E+13
Low Dens. Res.	8.78E+12	7.84E+12	8.47E+12	8.09E+12	8.25E+12	7.89E+12	7.94E+12	7.94E+12	7.68E+12	7.83E+12	7.68E+12	8.36E+12	9.67E+13
Pasture	9.15E+13	8.26E+13	9.09E+13	8.72E+13	9.01E+13	1.90E+14	1.93E+14	1.93E+14	8.72E+13	9.09E+13	8.80E+13	9.15E+13	1.38E+15
Row Crop	3.75E+11	3.39E+11	4.15E+14	4.15E+14	4.15E+14	3.63E+11	3.75E+11	3.75E+11	4.15E+14	3.11E+14	1.04E+14	3.75E+11	2.08E+15
Wetlands	5.83E+12	5.27E+12	5.83E+12	5.64E+12	5.83E+12	5.64E+12	5.83E+12	5.83E+12	5.64E+12	5.83E+12	5.64E+12	5.83E+12	6.87E+13

Table B.3 **Current conditions of land applied fecal coliform loads for Beaverdam Creek impairment by land use (subwatersheds 17,18,21).**

Land-use	January	February	March	April	May	June	July	August	September	October	November	December	Annual Total Loads (cfu/yr)
Barren	3.04E+10	2.75E+10	3.04E+10	2.95E+10	3.04E+10	2.95E+10	3.04E+10	3.04E+10	2.95E+10	3.04E+10	2.95E+10	3.04E+10	3.58E+11
Commercial	4.71E+08	4.25E+08	4.71E+08	4.56E+08	4.71E+08	4.56E+08	4.71E+08	4.71E+08	4.56E+08	4.71E+08	4.56E+08	4.71E+08	5.55E+09
Forest	2.26E+13	2.04E+13	2.26E+13	2.18E+13	2.26E+13	2.18E+13	2.26E+13	2.26E+13	2.18E+13	2.26E+13	2.18E+13	2.26E+13	2.66E+14
Livestock Access	1.98E+12	1.79E+12	2.69E+12	3.53E+12	3.65E+12	4.22E+12	4.36E+12	4.36E+12	3.53E+12	2.69E+12	2.61E+12	1.98E+12	3.74E+13
Low Dens. Res.	9.66E+12	8.63E+12	9.33E+12	8.93E+12	9.11E+12	8.71E+12	8.79E+12	8.79E+12	8.50E+12	8.68E+12	8.50E+12	9.22E+12	1.07E+14
Pasture	1.20E+14	1.08E+14	1.18E+14	1.13E+14	1.17E+14	1.28E+14	1.32E+14	1.32E+14	1.13E+14	1.18E+14	1.15E+14	1.20E+14	1.43E+15
Row Crop	1.61E+13	1.60E+13	1.56E+14	1.56E+14	3.93E+13	5.72E+11	5.91E+11	5.91E+11	1.63E+14	1.56E+14	1.61E+13	1.61E+13	7.35E+14
Wetlands	3.20E+12	2.89E+12	3.20E+12	3.10E+12	3.20E+12	3.10E+12	3.20E+12	3.20E+12	3.10E+12	3.20E+12	3.10E+12	3.20E+12	3.77E+13

Table B.4 **Current conditions of land applied fecal coliform loads for Fine Creek impairment by land use (subwatershed 19).**

Land-use	January	February	March	April	May	June	July	August	September	October	November	December	Annual Total Loads (cfu/yr)
Barren	4.60E+10	4.15E+10	4.60E+10	4.45E+10	4.60E+10	4.45E+10	4.60E+10	4.60E+10	4.45E+10	4.60E+10	4.45E+10	4.60E+10	5.42E+11
Commercial	5.28E+08	4.77E+08	5.28E+08	5.11E+08	5.28E+08	5.11E+08	5.28E+08	5.28E+08	5.11E+08	5.28E+08	5.11E+08	5.28E+08	6.22E+09
Forest	1.89E+13	1.71E+13	1.89E+13	1.83E+13	1.89E+13	1.83E+13	1.89E+13	1.89E+13	1.83E+13	1.89E+13	1.83E+13	1.89E+13	2.23E+14
Livestock Access	7.55E+11	6.82E+11	1.04E+12	1.37E+12	1.41E+12	1.64E+12	1.69E+12	1.69E+12	1.37E+12	1.04E+12	1.00E+12	7.55E+11	1.44E+13
Low Dens. Res.	5.14E+12	4.61E+12	5.01E+12	4.81E+12	4.93E+12	4.73E+12	4.80E+12	4.80E+12	4.65E+12	4.76E+12	4.65E+12	4.97E+12	5.79E+13
Pasture	6.02E+13	5.44E+13	5.98E+13	5.74E+13	5.93E+13	5.70E+13	5.89E+13	5.89E+13	5.74E+13	5.98E+13	5.79E+13	6.02E+13	7.01E+14
Row Crop	2.88E+11	2.60E+11	2.88E+11	2.79E+11	2.88E+11	2.79E+11	2.88E+11	2.88E+11	2.79E+11	2.88E+11	2.79E+11	2.88E+11	3.39E+12
Wetlands	2.54E+12	2.29E+12	2.54E+12	2.45E+12	2.54E+12	2.45E+12	2.54E+12	2.54E+12	2.45E+12	2.54E+12	2.45E+12	2.54E+12	2.99E+13

Table B.5 **Current conditions of land applied fecal coliform loads for Upper James River impairment by land use (subwatershed 1,2,3,4,31,32,33,34 (not including Byrd Creek and Big & Little Lickinghole Creek subwatersheds)).**

Land-use	January	February	March	April	May	June	July	August	September	October	November	December	Annual Total Loads (cfu/yr)
Barren	1.43E+11	1.29E+11	1.43E+11	1.38E+11	1.43E+11	1.38E+11	1.43E+11	1.43E+11	1.38E+11	1.43E+11	1.38E+11	1.43E+11	1.68E+12
Forest	7.35E+13	6.64E+13	7.35E+13	7.12E+13	7.35E+13	7.12E+13	7.35E+13	7.35E+13	7.12E+13	7.35E+13	7.12E+13	7.35E+13	8.66E+14
Livestock Access	5.39E+12	4.87E+12	7.50E+12	9.99E+12	1.03E+13	1.20E+13	1.24E+13	1.24E+13	9.99E+12	7.50E+12	7.26E+12	5.39E+12	1.05E+14
Low Dens. Res.	1.62E+13	1.44E+13	1.55E+13	1.48E+13	1.51E+13	1.44E+13	1.45E+13	1.45E+13	1.40E+13	1.42E+13	1.40E+13	1.53E+13	1.77E+14
Pasture	3.32E+14	3.00E+14	3.29E+14	3.14E+14	3.25E+14	5.69E+14	5.79E+14	5.79E+14	3.14E+14	3.29E+14	3.18E+14	3.32E+14	4.62E+15
Row Crop	5.79E+13	5.78E+13	1.37E+15	1.37E+15	9.45E+14	1.02E+12	1.05E+12	1.05E+12	1.40E+15	1.17E+15	2.58E+14	5.79E+13	6.69E+15
Wetlands	9.14E+12	8.25E+12	9.14E+12	8.84E+12	9.14E+12	8.84E+12	9.14E+12	9.14E+12	8.84E+12	9.14E+12	8.84E+12	9.14E+12	1.08E+14

Table B.6 **Current conditions of land applied fecal coliform loads for Lower James River impairment by land use (subwatershed 5 (not including Byrd Creek, Big & Little Lickinghole Creek, or Upper James River impairment subwatersheds)).**

Land-use	January	February	March	April	May	June	July	August	September	October	November	December	Annual Total Loads (cfu/yr)
Barren	1.29E+10	1.16E+10	1.29E+10	1.24E+10	1.29E+10	1.24E+10	1.29E+10	1.29E+10	1.24E+10	1.29E+10	1.24E+10	1.29E+10	1.51E+11
Commercial	2.59E+08	2.34E+08	2.59E+08	2.50E+08	2.59E+08	2.50E+08	2.59E+08	2.59E+08	2.50E+08	2.59E+08	2.50E+08	2.59E+08	3.05E+09
Forest	1.32E+13	1.20E+13	1.32E+13	1.28E+13	1.32E+13	1.28E+13	1.32E+13	1.32E+13	1.28E+13	1.32E+13	1.28E+13	1.32E+13	1.56E+14
Livestock Access	1.60E+12	1.45E+12	2.19E+12	2.88E+12	2.97E+12	3.45E+12	3.56E+12	3.56E+12	2.88E+12	2.19E+12	2.12E+12	1.60E+12	3.04E+13
Low Dens. Res.	4.58E+12	4.08E+12	4.40E+12	4.20E+12	4.28E+12	4.08E+12	4.10E+12	4.10E+12	3.97E+12	4.04E+12	3.97E+12	4.34E+12	5.01E+13
Pasture	1.04E+14	9.41E+13	1.03E+14	9.90E+13	1.02E+14	1.36E+14	1.39E+14	1.39E+14	9.90E+13	1.03E+14	1.00E+14	1.04E+14	1.32E+15
Row Crop	1.28E+13	1.27E+13	2.25E+14	2.25E+14	1.32E+14	3.63E+11	3.76E+11	3.76E+11	2.31E+14	2.00E+14	3.79E+13	1.28E+13	1.09E+15
Wetlands	9.82E+11	8.87E+11	9.82E+11	9.50E+11	9.82E+11	9.50E+11	9.82E+11	9.82E+11	9.50E+11	9.82E+11	9.50E+11	9.82E+11	1.16E+13

Table B.7 **Monthly, directly deposited fecal coliform loads in each reach of Byrd Creek Impairment (subwatersheds 10,11,12,13,20).**

Source Type	Reach ID	January	February	March	April	May	June	July	August	September	October	November	December	Annual Total Loads (cfu/yr)
Human/Pet	10	6.49E+11	5.86E+11	6.49E+11	6.28E+11	6.49E+11	6.28E+11	6.49E+11	6.49E+11	6.28E+11	6.49E+11	6.28E+11	6.49E+11	7.64E+12
Livestock	10	5.42E+11	4.90E+11	7.75E+11	1.05E+12	1.08E+12	1.27E+12	1.32E+12	1.32E+12	1.05E+12	7.75E+11	7.50E+11	5.42E+11	1.10E+13
Wildlife	10	3.19E+11	2.88E+11	3.19E+11	3.09E+11	3.19E+11	3.09E+11	3.19E+11	3.19E+11	3.09E+11	3.19E+11	3.09E+11	3.19E+11	3.76E+12
Human/Pet	11	5.34E+11	4.83E+11	5.34E+11	5.17E+11	5.34E+11	5.17E+11	5.34E+11	5.34E+11	5.17E+11	5.34E+11	5.17E+11	5.34E+11	6.29E+12
Livestock	11	1.06E+11	9.55E+10	1.51E+11	2.05E+11	2.11E+11	2.48E+11	2.57E+11	2.57E+11	2.05E+11	1.51E+11	1.46E+11	1.06E+11	2.14E+12
Wildlife	11	1.61E+11	1.45E+11	1.61E+11	1.56E+11	1.61E+11	1.56E+11	1.61E+11	1.61E+11	1.56E+11	1.61E+11	1.56E+11	1.61E+11	1.89E+12
Human/Pet	12	2.32E+11	2.09E+11	2.32E+11	2.24E+11	2.32E+11	2.24E+11	2.32E+11	2.32E+11	2.24E+11	2.32E+11	2.24E+11	2.32E+11	2.73E+12
Livestock	12	4.84E+10	4.37E+10	6.91E+10	9.36E+10	9.67E+10	1.14E+11	1.17E+11	1.17E+11	9.36E+10	6.91E+10	6.69E+10	4.84E+10	9.78E+11
Wildlife	12	2.50E+10	2.26E+10	2.50E+10	2.42E+10	2.50E+10	2.42E+10	2.50E+10	2.50E+10	2.42E+10	2.50E+10	2.42E+10	2.50E+10	2.95E+11
Human/Pet	13	1.25E+12	1.13E+12	1.25E+12	1.21E+12	1.25E+12	1.21E+12	1.25E+12	1.25E+12	1.21E+12	1.25E+12	1.21E+12	1.25E+12	1.47E+13
Livestock	13	4.66E+11	4.21E+11	6.66E+11	9.02E+11	9.32E+11	1.10E+12	1.13E+12	1.13E+12	9.02E+11	6.66E+11	6.44E+11	4.66E+11	9.42E+12
Wildlife	13	2.95E+11	2.66E+11	2.95E+11	2.85E+11	2.95E+11	2.85E+11	2.95E+11	2.95E+11	2.85E+11	2.95E+11	2.85E+11	2.95E+11	3.47E+12
Human/Pet	20	5.98E+11	5.40E+11	5.98E+11	5.79E+11	5.98E+11	5.79E+11	5.98E+11	5.98E+11	5.79E+11	5.98E+11	5.79E+11	5.98E+11	7.04E+12
Livestock	20	1.95E+11	1.76E+11	2.79E+11	3.78E+11	3.90E+11	4.59E+11	4.74E+11	4.74E+11	3.78E+11	2.79E+11	2.70E+11	1.95E+11	3.95E+12
Wildlife	20	1.13E+11	1.02E+11	1.13E+11	1.09E+11	1.13E+11	1.09E+11	1.13E+11	1.13E+11	1.09E+11	1.13E+11	1.09E+11	1.13E+11	1.33E+12

Table B.8 Monthly, directly deposited fecal coliform loads in Big & Little Lickinghole impairment (subwatersheds 14,15,16).

Source Type	Reach ID	January	February	March	April	May	June	July	August	September	October	November	December	Annual Total Loads (cfu/yr)
Human/Pet	14	7.70E+11	6.95E+11	7.70E+11	7.45E+11	7.70E+11	7.45E+11	7.70E+11	7.70E+11	7.45E+11	7.70E+11	7.45E+11	7.70E+11	9.06E+12
Livestock	14	9.24E+10	8.35E+10	1.32E+11	1.79E+11	1.85E+11	2.17E+11	2.24E+11	2.24E+11	1.79E+11	1.32E+11	1.28E+11	9.24E+10	1.87E+12
Wildlife	14	1.97E+11	1.78E+11	1.97E+11	1.91E+11	1.97E+11	1.91E+11	1.97E+11	1.97E+11	1.91E+11	1.97E+11	1.91E+11	1.97E+11	2.33E+12
Human/Pet	15	4.95E+10	4.47E+10	4.95E+10	4.79E+10	4.95E+10	4.79E+10	4.95E+10	4.95E+10	4.79E+10	4.95E+10	4.79E+10	4.95E+10	5.82E+11
Livestock	15	6.08E+10	5.49E+10	8.68E+10	1.18E+11	1.22E+11	1.43E+11	1.48E+11	1.48E+11	1.18E+11	8.68E+10	8.40E+10	6.08E+10	1.23E+12
Wildlife	15	2.79E+10	2.52E+10	2.79E+10	2.70E+10	2.79E+10	2.70E+10	2.79E+10	2.79E+10	2.70E+10	2.79E+10	2.70E+10	2.79E+10	3.29E+11
Human/Pet	16	6.32E+11	5.71E+11	6.32E+11	6.12E+11	6.32E+11	6.12E+11	6.32E+11	6.32E+11	6.12E+11	6.32E+11	6.12E+11	6.32E+11	7.44E+12
Livestock	16	2.55E+11	2.30E+11	3.64E+11	4.93E+11	5.09E+11	5.99E+11	6.19E+11	6.19E+11	4.93E+11	3.64E+11	3.52E+11	2.55E+11	5.15E+12
Wildlife	16	2.82E+11	2.54E+11	2.82E+11	2.73E+11	2.82E+11	2.73E+11	2.82E+11	2.82E+11	2.73E+11	2.82E+11	2.73E+11	2.82E+11	3.32E+12

Table B.9 Monthly, directly deposited fecal coliform loads in Beaverdam Creek impairment (subwatersheds 17,18,21).

Source Type	Reach ID	January	February	March	April	May	June	July	August	September	October	November	December	Annual Total Loads (cfu/yr)
Human/Pet	17	1.69E+12	1.52E+12	1.69E+12	1.63E+12	1.69E+12	1.63E+12	1.69E+12	1.69E+12	1.63E+12	1.69E+12	1.63E+12	1.69E+12	1.99E+13
Livestock	17	3.19E+11	2.88E+11	4.56E+11	6.18E+11	6.39E+11	7.51E+11	7.76E+11	7.76E+11	6.18E+11	4.56E+11	4.41E+11	3.19E+11	6.46E+12
Wildlife	17	1.94E+11	1.75E+11	1.94E+11	1.88E+11	1.94E+11	1.88E+11	1.94E+11	1.94E+11	1.88E+11	1.94E+11	1.88E+11	1.94E+11	2.28E+12
Human/Pet	18	3.47E+11	3.13E+11	3.47E+11	3.35E+11	3.47E+11	3.35E+11	3.47E+11	3.47E+11	3.35E+11	3.47E+11	3.35E+11	3.47E+11	4.08E+12
Livestock	18	2.51E+11	2.27E+11	3.59E+11	4.86E+11	5.02E+11	5.90E+11	6.10E+11	6.10E+11	4.86E+11	3.59E+11	3.47E+11	2.51E+11	5.08E+12
Wildlife	18	4.86E+10	4.39E+10	4.86E+10	4.70E+10	4.86E+10	4.70E+10	4.86E+10	4.86E+10	4.70E+10	4.86E+10	4.70E+10	4.86E+10	5.72E+11
Human/Pet	21	4.96E+11	4.48E+11	4.96E+11	4.80E+11	4.96E+11	4.80E+11	4.96E+11	4.96E+11	4.80E+11	4.96E+11	4.80E+11	4.96E+11	5.84E+12
Livestock	21	1.45E+11	1.31E+11	2.07E+11	2.80E+11	2.89E+11	3.40E+11	3.52E+11	3.52E+11	2.80E+11	2.07E+11	2.00E+11	1.45E+11	2.93E+12
Wildlife	21	1.35E+11	1.21E+11	1.35E+11	1.30E+11	1.35E+11	1.30E+11	1.35E+11	1.35E+11	1.30E+11	1.35E+11	1.30E+11	1.35E+11	1.58E+12

Table B.10 Monthly, directly deposited fecal coliform loads in Fine Creek impairment (subwatershed 19).

Source Type	Reach ID	January	February	March	April	May	June	July	August	September	October	November	December	Annual Total Loads (cfu/yr)
Human/Pet	19	5.98E+11	5.40E+11	5.98E+11	5.79E+11	5.98E+11	5.79E+11	5.98E+11	5.98E+11	5.79E+11	5.98E+11	5.79E+11	5.98E+11	7.04E+12
Livestock	19	2.81E+11	2.54E+11	4.02E+11	5.45E+11	5.63E+11	6.62E+11	6.84E+11	6.84E+11	5.45E+11	4.02E+11	3.89E+11	2.81E+11	5.69E+12
Wildlife	19	1.75E+11	1.58E+11	1.75E+11	1.69E+11	1.75E+11	1.69E+11	1.75E+11	1.75E+11	1.69E+11	1.75E+11	1.69E+11	1.75E+11	2.06E+12

Table B.11 **Monthly, directly deposited fecal coliform loads in Upper James River impairment (subwatershed 1,2,3,4,31,32,33,34 (not including Byrd Creek and Big & Little Lickinghole Creek subwatersheds)).**

Source Type	Reach ID	January	February	March	April	May	June	July	August	September	October	November	December	Annual Total Loads (cfu/yr)
Human/Pet	1	1.26E+11	1.13E+11	1.26E+11	1.22E+11	1.26E+11	1.22E+11	1.26E+11	1.26E+11	1.22E+11	1.26E+11	1.22E+11	1.26E+11	1.48E+12
Livestock	1	1.24E+11	1.12E+11	1.77E+11	2.40E+11	2.48E+11	2.91E+11	3.01E+11	3.01E+11	2.40E+11	1.77E+11	1.71E+11	1.24E+11	2.51E+12
Wildlife	1	7.91E+10	7.15E+10	7.91E+10	7.66E+10	7.91E+10	7.66E+10	7.91E+10	7.91E+10	7.66E+10	7.91E+10	7.66E+10	7.91E+10	9.32E+11
Human/Pet	2	6.19E+11	5.59E+11	6.19E+11	5.99E+11	6.19E+11	5.99E+11	6.19E+11	6.19E+11	5.99E+11	6.19E+11	5.99E+11	6.19E+11	7.29E+12
Livestock	2	1.59E+11	1.44E+11	2.27E+11	3.08E+11	3.18E+11	3.74E+11	3.86E+11	3.86E+11	3.08E+11	2.27E+11	2.20E+11	1.59E+11	3.22E+12
Wildlife	2	6.54E+10	5.91E+10	6.54E+10	6.33E+10	6.54E+10	6.33E+10	6.54E+10	6.54E+10	6.33E+10	6.54E+10	6.33E+10	6.54E+10	7.71E+11
Human/Pet	3	8.28E+11	7.48E+11	8.28E+11	8.02E+11	8.28E+11	8.02E+11	8.28E+11	8.28E+11	8.02E+11	8.28E+11	8.02E+11	8.28E+11	9.75E+12
Livestock	3	1.37E+11	1.24E+11	1.96E+11	2.66E+11	2.75E+11	3.23E+11	3.33E+11	3.33E+11	2.66E+11	1.96E+11	1.90E+11	1.37E+11	2.78E+12
Wildlife	3	1.27E+11	1.15E+11	1.27E+11	1.23E+11	1.27E+11	1.23E+11	1.27E+11	1.27E+11	1.23E+11	1.27E+11	1.23E+11	1.27E+11	1.50E+12
Human/Pet	4	2.87E+11	2.59E+11	2.87E+11	2.78E+11	2.87E+11	2.78E+11	2.87E+11	2.87E+11	2.78E+11	2.87E+11	2.78E+11	2.87E+11	3.38E+12
Livestock	4	6.10E+11	5.51E+11	8.72E+11	1.18E+12	1.22E+12	1.43E+12	1.48E+12	1.48E+12	1.18E+12	8.72E+11	8.44E+11	6.10E+11	1.23E+13
Wildlife	4	1.21E+11	1.10E+11	1.21E+11	1.18E+11	1.21E+11	1.18E+11	1.21E+11	1.21E+11	1.18E+11	1.21E+11	1.18E+11	1.21E+11	1.43E+12
Human/Pet	31	3.39E+12	3.06E+12	3.39E+12	3.28E+12	3.39E+12	3.28E+12	3.39E+12	3.39E+12	3.28E+12	3.39E+12	3.28E+12	3.39E+12	3.99E+13
Livestock	31	5.51E+11	4.98E+11	7.87E+11	1.07E+12	1.10E+12	1.30E+12	1.34E+12	1.34E+12	1.07E+12	7.87E+11	7.62E+11	5.51E+11	1.11E+13
Wildlife	31	2.01E+11	1.82E+11	2.01E+11	1.95E+11	2.01E+11	1.95E+11	2.01E+11	2.01E+11	1.95E+11	2.01E+11	1.95E+11	2.01E+11	2.37E+12
Human/Pet	32	1.56E+12	1.41E+12	1.56E+12	1.51E+12	1.56E+12	1.51E+12	1.56E+12	1.56E+12	1.51E+12	1.56E+12	1.51E+12	1.56E+12	1.83E+13
Livestock	32	4.13E+11	3.73E+11	5.90E+11	7.99E+11	8.26E+11	9.70E+11	1.00E+12	1.00E+12	7.99E+11	5.90E+11	5.71E+11	4.13E+11	8.35E+12
Wildlife	32	2.80E+11	2.53E+11	2.80E+11	2.71E+11	2.80E+11	2.71E+11	2.80E+11	2.80E+11	2.71E+11	2.80E+11	2.71E+11	2.80E+11	3.29E+12
Human/Pet	33	1.04E+12	9.42E+11	1.04E+12	1.01E+12	1.04E+12	1.01E+12	1.04E+12	1.04E+12	1.01E+12	1.04E+12	1.01E+12	1.04E+12	1.23E+13
Livestock	33	8.16E+10	7.37E+10	1.17E+11	1.58E+11	1.63E+11	1.92E+11	1.98E+11	1.98E+11	1.58E+11	1.17E+11	1.13E+11	8.16E+10	1.65E+12
Wildlife	33	1.25E+11	1.13E+11	1.25E+11	1.21E+11	1.25E+11	1.21E+11	1.25E+11	1.25E+11	1.21E+11	1.25E+11	1.21E+11	1.25E+11	1.48E+12
Human/Pet	34	3.10E+11	2.80E+11	3.10E+11	3.00E+11	3.10E+11	3.00E+11	3.10E+11	3.10E+11	3.00E+11	3.10E+11	3.00E+11	3.10E+11	3.65E+12
Livestock	34	3.80E+10	3.43E+10	5.43E+10	7.36E+10	7.61E+10	8.94E+10	9.23E+10	9.23E+10	7.36E+10	5.43E+10	5.26E+10	3.80E+10	7.69E+11
Wildlife	34	3.36E+10	3.04E+10	3.36E+10	3.25E+10	3.36E+10	3.25E+10	3.36E+10	3.36E+10	3.25E+10	3.36E+10	3.25E+10	3.36E+10	3.96E+11

Table B.12 Monthly, directly deposited fecal coliform loads in Lower James River impairment (subwatershed 5 (not including Byrd Creek, Big & Little Lickinghole Creek, or Upper James River impairment subwatersheds)).

Source Type	Reach ID	January	February	March	April	May	June	July	August	September	October	November	December	Annual Total Loads (cfu/yr)
Human/Pet	5	6.09E+11	5.50E+11	6.09E+11	5.89E+11	6.09E+11	5.89E+11	6.09E+11	6.09E+11	5.89E+11	6.09E+11	5.89E+11	6.09E+11	7.17E+12
Livestock	5	5.89E+11	5.32E+11	8.41E+11	1.14E+12	1.18E+12	1.38E+12	1.43E+12	1.43E+12	1.14E+12	8.41E+11	8.14E+11	5.89E+11	1.19E+13
Wildlife	5	2.39E+11	2.16E+11	2.39E+11	2.31E+11	2.39E+11	2.31E+11	2.39E+11	2.39E+11	2.31E+11	2.39E+11	2.31E+11	2.39E+11	2.81E+12

Table B.13 Existing annual loads from land-based sources for Byrd Creek Impairment by land use (subwatersheds 10,11,12,13,20).

Source	Barren	Commercial	Forest	Livestock Access	Low Density Residential	Pasture	Row Crop	Water	Wetlands
beaver	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.11E+10	0.00E+00
beef_calf	0.00E+00	0.00E+00	0.00E+00	1.23E+13	0.00E+00	3.34E+14	0.00E+00	5.28E+12	0.00E+00
beef_cow	0.00E+00	0.00E+00	0.00E+00	3.89E+13	0.00E+00	1.05E+15	0.00E+00	1.67E+13	0.00E+00
Cat	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.95E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00
dairy_calf	0.00E+00	0.00E+00	0.00E+00	3.77E+12	0.00E+00	1.02E+14	0.00E+00	1.62E+12	0.00E+00
dairy_milker	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.43E+13	1.32E+15	0.00E+00	0.00E+00
dairy_repl	0.00E+00	0.00E+00	0.00E+00	9.10E+12	0.00E+00	2.47E+14	0.00E+00	3.90E+12	0.00E+00
Deer	0.00E+00	0.00E+00	2.05E+14	6.27E+11	6.64E+12	4.28E+13	7.02E+11	0.00E+00	7.21E+12
Dog	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.57E+13	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Duck	3.58E+07	0.00E+00	5.22E+10	1.60E+09	1.04E+09	7.11E+09	1.08E+08	0.00E+00	1.81E+10
Failing_Septic	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.96E+13	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Goose	3.88E+09	0.00E+00	5.67E+12	1.73E+11	1.13E+11	7.72E+11	1.18E+10	0.00E+00	1.96E+12
Hog_CAFO	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Hog_non_CAFO	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.11E+13	0.00E+00	0.00E+00	0.00E+00
horse	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.20E+14	0.00E+00	0.00E+00	0.00E+00
Muskrat	8.66E+10	0.00E+00	1.26E+14	3.87E+12	2.51E+12	1.72E+13	2.62E+11	0.00E+00	4.37E+13
poultry	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Raccoon	3.76E+11	0.00E+00	1.64E+14	8.26E+11	4.91E+12	3.42E+13	6.04E+11	0.00E+00	1.20E+13
sheep	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.44E+11	0.00E+00	0.00E+00	0.00E+00
Str_Pipe	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.84E+13	0.00E+00
Turkey	0.00E+00	0.00E+00	7.05E+10	5.40E+07	0.00E+00	3.69E+09	6.05E+07	0.00E+00	2.48E+09

Table B.14 Existing annual loads from land-based sources for Big & Little Lickinghole impairment by land use (subwatersheds 14,15,16).

Source	Barren	Commercial	Forest	Livestock Access	Low Density	Pasture	Row Crop	Water	Wetlands
beaver	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.36E+10	0.00E+00
beef_calf	0.00E+00	0.00E+00	0.00E+00	4.31E+12	0.00E+00	1.17E+14	0.00E+00	1.85E+12	0.00E+00
beef_cow	0.00E+00	0.00E+00	0.00E+00	1.49E+13	0.00E+00	4.05E+14	0.00E+00	6.40E+12	0.00E+00
Cat	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.42E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00
dairy_calf	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
dairy_milker	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
dairy_repl	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Deer	0.00E+00	0.00E+00	1.59E+14	4.97E+11	5.35E+12	3.03E+13	1.82E+12	0.00E+00	8.58E+12
Dog	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.99E+13	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Duck	3.75E+07	0.00E+00	2.26E+10	5.30E+08	7.55E+08	2.75E+09	2.07E+08	0.00E+00	1.49E+10
Failing_Septic	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.32E+13	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Goose	4.07E+09	0.00E+00	2.45E+12	5.76E+10	8.20E+10	2.99E+11	2.25E+10	0.00E+00	1.62E+12
Hog_CAFO	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Hog_non_CAFO	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.84E+13	0.00E+00	0.00E+00	0.00E+00
horse	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.53E+14	0.00E+00	0.00E+00	0.00E+00
Muskrat	9.07E+10	0.00E+00	5.46E+13	1.28E+12	1.83E+12	6.66E+12	5.01E+11	0.00E+00	3.61E+13
poultry	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.11E+14	2.07E+15	0.00E+00	0.00E+00
Raccoon	6.89E+11	0.00E+00	1.89E+14	7.30E+11	6.43E+12	3.57E+13	2.07E+12	0.00E+00	2.24E+13
sheep	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.79E+11	0.00E+00	0.00E+00	0.00E+00
Str_Pipe	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.71E+13	0.00E+00
Turkey	0.00E+00	0.00E+00	4.39E+10	3.43E+07	0.00E+00	2.09E+09	1.25E+08	0.00E+00	2.36E+09

Table B.15 Existing annual loads from land-based sources for Beaverdam Creek impairment by land use (subwatersheds 17,18,21).

Source	Barren	Commercial	Forest	Livestock Access	Low Density	Pasture	Row Crop	Water	Wetlands
beaver	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.75E+09	0.00E+00
beef_calf	0.00E+00	0.00E+00	0.00E+00	6.47E+12	0.00E+00	1.75E+14	0.00E+00	2.77E+12	0.00E+00
beef_cow	0.00E+00	0.00E+00	0.00E+00	2.02E+13	0.00E+00	5.47E+14	0.00E+00	8.65E+12	0.00E+00
Cat	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.91E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00
dairy_calf	0.00E+00	0.00E+00	0.00E+00	2.08E+12	0.00E+00	5.64E+13	0.00E+00	8.92E+11	0.00E+00
dairy_milker	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.65E+13	7.28E+14	0.00E+00	0.00E+00
dairy_repl	0.00E+00	0.00E+00	0.00E+00	5.02E+12	0.00E+00	1.36E+14	0.00E+00	2.15E+12	0.00E+00
Deer	0.00E+00	0.00E+00	1.12E+14	6.90E+11	8.19E+12	3.64E+13	3.28E+12	0.00E+00	6.10E+12
Dog	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.53E+13	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Duck	1.26E+07	0.00E+00	1.80E+10	7.93E+08	7.35E+08	3.87E+09	3.72E+08	0.00E+00	7.99E+09
Failing_Septic	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.40E+13	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Goose	1.36E+09	0.00E+00	1.95E+12	8.61E+10	7.97E+10	4.20E+11	4.04E+10	0.00E+00	8.67E+11
Hog_CAFO	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Hog_non_CAFO	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.41E+13	0.00E+00	0.00E+00	0.00E+00
horse	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.77E+14	0.00E+00	0.00E+00	0.00E+00
Muskrat	3.04E+10	0.00E+00	4.36E+13	1.92E+12	1.78E+12	9.35E+12	9.00E+11	0.00E+00	1.93E+13
poultry	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Raccoon	3.27E+11	5.55E+09	1.08E+14	9.39E+11	7.50E+12	3.54E+13	2.74E+12	0.00E+00	1.14E+13
sheep	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.26E+11	0.00E+00	0.00E+00	0.00E+00
Str_Pipe	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.98E+13	0.00E+00
Turkey	0.00E+00	0.00E+00	2.15E+10	3.30E+07	0.00E+00	1.74E+09	1.57E+08	0.00E+00	1.17E+09

Table B.16 Existing annual loads from land-based sources for Fine Creek impairment by land use (subwatershed 19).

Source	Barren	Commercial	Forest	Livestock Access	Low Density Residential	Pasture	RowCrop	Water	Wetlands
beaver	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.42E+09	0.00E+00
beef_calf	0.00E+00	0.00E+00	0.00E+00	4.31E+12	0.00E+00	1.17E+14	0.00E+00	1.85E+12	0.00E+00
beef_cow	0.00E+00	0.00E+00	0.00E+00	8.97E+12	0.00E+00	2.43E+14	0.00E+00	3.84E+12	0.00E+00
Cat	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.18E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00
dairy_calf	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
dairy_milker	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
dairy_repl	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Deer	0.00E+00	0.00E+00	1.48E+14	4.82E+11	8.28E+12	4.27E+13	2.45E+12	0.00E+00	1.02E+13
Dog	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.51E+13	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Duck	8.86E+06	0.00E+00	7.08E+09	1.68E+08	5.42E+08	1.57E+09	4.24E+07	0.00E+00	4.56E+09
Failing_Septic	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.26E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Goose	9.61E+08	0.00E+00	7.68E+11	1.82E+10	5.88E+10	1.71E+11	4.60E+09	0.00E+00	4.94E+11
Hog_CAFO	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Hog_non_CAFO	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
horse	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.78E+14	0.00E+00	0.00E+00	0.00E+00
Muskrat	2.14E+10	0.00E+00	1.71E+13	4.07E+11	1.31E+12	3.80E+12	1.03E+11	0.00E+00	1.10E+13
poultry	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Raccoon	5.19E+11	6.22E+09	5.66E+13	2.45E+11	3.82E+12	1.68E+13	8.28E+11	0.00E+00	8.12E+12
sheep	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.13E+11	0.00E+00	0.00E+00	0.00E+00
Str_Pipe	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.04E+12	0.00E+00
Turkey	0.00E+00	0.00E+00	1.28E+10	1.04E+07	0.00E+00	9.19E+08	5.29E+07	0.00E+00	8.80E+08

Table B.17 Existing annual loads from land-based sources for Upper James River impairment by land use (subwatershed 1,2,3,4,31,32,33,34 (not including Byrd Creek and Big & Little Lickinghole Creek subwatersheds)).

Source	Barren	Commercial	Forest	Livestock Access	Low Density Residential	Pasture	RowCrop	Water	Wetlands
beaver	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.77E+10	0.00E+00
beef_calf	0.00E+00	0.00E+00	0.00E+00	1.94E+13	0.00E+00	5.24E+14	0.00E+00	8.30E+12	0.00E+00
beef_cow	0.00E+00	0.00E+00	0.00E+00	5.44E+13	0.00E+00	1.47E+15	0.00E+00	2.33E+13	0.00E+00
Cat	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.75E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00
dairy_calf	0.00E+00	0.00E+00	0.00E+00	7.63E+12	0.00E+00	2.07E+14	0.00E+00	3.27E+12	0.00E+00
dairy_milker	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.70E+14	2.67E+15	0.00E+00	0.00E+00
dairy_repl	0.00E+00	0.00E+00	0.00E+00	1.84E+13	0.00E+00	4.99E+14	0.00E+00	7.89E+12	0.00E+00
Deer	0.00E+00	0.00E+00	3.11E+14	8.83E+11	8.98E+12	6.92E+13	4.02E+12	0.00E+00	1.29E+13
Dog	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.08E+14	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Duck	6.82E+06	0.00E+00	5.15E+10	1.11E+09	7.27E+08	9.19E+09	6.36E+08	0.00E+00	2.21E+10
Failing_Septic	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.72E+13	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Goose	7.40E+08	0.00E+00	5.59E+12	1.21E+11	7.89E+10	9.98E+11	6.90E+10	0.00E+00	2.40E+12
Hog_CAFO	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Hog_non_CAFO	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.88E+13	0.00E+00	0.00E+00	0.00E+00
horse	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.34E+14	0.00E+00	0.00E+00	0.00E+00
Muskrat	1.65E+10	0.00E+00	1.25E+14	2.69E+12	1.76E+12	2.22E+13	1.54E+12	0.00E+00	5.35E+13
poultry	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.01E+14	4.01E+15	0.00E+00	0.00E+00
Raccoon	1.66E+12	0.00E+00	4.25E+14	1.67E+12	1.13E+13	1.01E+14	6.73E+12	0.00E+00	3.88E+13
sheep	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.12E+12	0.00E+00	0.00E+00	0.00E+00
Str_Pipe	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.60E+13	0.00E+00
Turkey	0.00E+00	0.00E+00	1.07E+11	7.61E+07	0.00E+00	5.96E+09	3.46E+08	0.00E+00	4.44E+09

Table B.18 Existing annual loads from land-based sources for Lower James River impairment by land use (subwatershed 5 (not including Byrd Creek, Big & Little Lickinghole Creek, or Upper James River impairment subwatersheds)).

Source	Barren	Commercial	Forest	Livestock Access	Low Density Residential	Pasture	RowCrop	Water	Wetlands
beaver	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.04E+10	0.00E+00
beef_calf	0.00E+00	0.00E+00	0.00E+00	5.11E+12	0.00E+00	1.38E+14	0.00E+00	2.19E+12	0.00E+00
beef_cow	0.00E+00	0.00E+00	0.00E+00	1.70E+13	0.00E+00	4.60E+14	0.00E+00	7.28E+12	0.00E+00
Cat	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.62E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00
dairy_calf	0.00E+00	0.00E+00	0.00E+00	1.66E+12	0.00E+00	4.51E+13	0.00E+00	7.13E+11	0.00E+00
dairy_milker	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.72E+13	5.83E+14	0.00E+00	0.00E+00
dairy_repl	0.00E+00	0.00E+00	0.00E+00	4.02E+12	0.00E+00	1.09E+14	0.00E+00	1.72E+12	0.00E+00
Deer	0.00E+00	0.00E+00	4.60E+13	2.10E+11	2.67E+12	1.47E+13	1.32E+12	0.00E+00	1.34E+12
Dog	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.90E+13	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Duck	2.07E+07	0.00E+00	1.30E+10	7.22E+08	4.10E+08	3.31E+09	3.00E+08	0.00E+00	2.48E+09
Failing_Septic	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.31E+13	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Goose	2.24E+09	0.00E+00	1.41E+12	7.84E+10	4.45E+10	3.59E+11	3.25E+10	0.00E+00	2.69E+11
Hog_CAFO	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Hog_non_CAFO	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.60E+12	0.00E+00	0.00E+00	0.00E+00
horse	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.05E+14	0.00E+00	0.00E+00	0.00E+00
Muskrat	5.00E+10	0.00E+00	3.14E+13	1.75E+12	9.92E+11	8.00E+12	7.25E+11	0.00E+00	6.00E+12
poultry	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.53E+13	5.02E+14	0.00E+00	0.00E+00
Raccoon	9.90E+10	3.05E+09	7.70E+13	6.29E+11	4.33E+12	2.61E+13	2.34E+12	0.00E+00	3.95E+12
sheep	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.06E+11	0.00E+00	0.00E+00	0.00E+00
Str_Pipe	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.17E+12	0.00E+00
Turkey	0.00E+00	0.00E+00	1.59E+10	1.80E+07	0.00E+00	1.27E+09	1.14E+08	0.00E+00	4.61E+08

Table B.19 Existing annual loads from direct-deposition sources for Byrd Creek Impairment (subwatersheds 10,11,12,13,20).

Source	Annual Total Loads (cfu/yr)
beaver	3.11E+10
beef_calf	5.28E+12
beef_cow	1.67E+13
dairy_calf	1.62E+12
dairy_milker	0.00E+00
dairy_repl	3.90E+12
Deer	1.32E+11
Duck	3.35E+09
Goose	2.39E+11
Hog_non_CAFO	0.00E+00
horse	0.00E+00
Muskrat	9.79E+12
poultry	0.00E+00
Raccoon	5.48E+11
sheep	0.00E+00
Str_Pipe	3.84E+13
Turkey	3.87E+07

Table B.20 Existing annual loads from direct-deposition sources for Big & Little Lickinghole impairment (subwatersheds 14,15,16).

Source	Annual Total Loas (cfu/yr)
beaver	1.36E+10
beef_calf	1.85E+12
beef_cow	6.40E+12
dairy_calf	0.00E+00
dairy_milker	0.00E+00
dairy_repl	0.00E+00
Deer	1.04E+11
Duck	1.74E+09
Goose	1.24E+11
Hog_non_CAFO	0.00E+00
horse	0.00E+00
Muskrat	5.08E+12
poultry	0.00E+00
Raccoon	6.48E+11
sheep	0.00E+00
Str_Pipe	1.71E+13
Turkey	2.44E+07

Table B.21 Existing annual loads from direct-deposition sources for Beaverdam Creek impairment (subwatersheds 17,18,21).

Source	Annual Total Loas (cfu/yr)
beaver	9.75E+09
beef_calf	2.77E+12
beef_cow	8.65E+12
dairy_calf	8.92E+11
dairy_milker	0.00E+00
dairy_repl	2.15E+12
Deer	8.41E+10
Duck	1.31E+09
Goose	9.36E+10
Hog_non_CAFO	0.00E+00
horse	0.00E+00
Muskrat	3.83E+12
poultry	0.00E+00
Raccoon	4.20E+11
sheep	0.00E+00
Str_Pipe	2.98E+13
Turkey	1.24E+07

Table B.22 Existing annual loads from direct-deposition sources for Fine Creek impairment (subwatershed 19).

Source	Annual Total Loas (cfu/yr)
beaver	4.42E+09
beef_calf	1.85E+12
beef_cow	3.84E+12
dairy_calf	0.00E+00
dairy_milker	0.00E+00
dairy_repl	0.00E+00
Deer	1.07E+11
Duck	5.75E+08
Goose	4.11E+10
Hog_non_CAFO	0.00E+00
horse	0.00E+00
Muskrat	1.68E+12
poultry	0.00E+00
Raccoon	2.19E+11
sheep	0.00E+00
Str_Pipe	7.04E+12
Turkey	7.37E+06

Table B.23 Existing annual loads from direct-deposition sources for Upper James River impairment (subwatershed 1,2,3,4,31,32,33,34 (not including Byrd Creek and Big & Little Lickinghole Creek subwatersheds)).

Source	Annual Total Loas (cfu/yr)
beaver	3.77E+10
beef_calf	8.30E+12
beef_cow	2.33E+13
dairy_calf	3.27E+12
dairy_milker	0.00E+00
dairy_repl	7.89E+12
Deer	2.05E+11
Duck	3.49E+09
Goose	2.49E+11
Hog_non_CAFO	0.00E+00
horse	0.00E+00
Muskrat	1.02E+13
poultry	0.00E+00
Raccoon	1.47E+12
sheep	0.00E+00
Str_Pipe	9.60E+13
Turkey	5.94E+07
poultry	0.00E+00
Raccoon	1.47E+12
sheep	0.00E+00
Str_Pipe	9.60E+13
Turkey	5.94E+07

Table B.24 Existing annual loads from direct-deposition sources for Lower James River impairment (subwatershed 5 (not including Byrd Creek, Big & Little Lickinghole Creek, or Upper James River impairment subwatersheds)).

Source	Annual Total Loas (cfu/yr)
beaver	1.04E+10
beef_calf	2.19E+12
beef_cow	7.28E+12
dairy_calf	7.13E+11
dairy_milker	0.00E+00
dairy_repl	1.72E+12
Deer	3.35E+10
Duck	8.28E+08
Goose	5.91E+10
Hog_non_CAFO	0.00E+00
horse	0.00E+00
Muskrat	2.42E+12
poultry	0.00E+00
Raccoon	2.88E+11
sheep	0.00E+00
Str_Pipe	7.17E+12
Turkey	8.97E+06

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APPENDIX C

Concentration – Discharge by Water Quality Monitoring Station

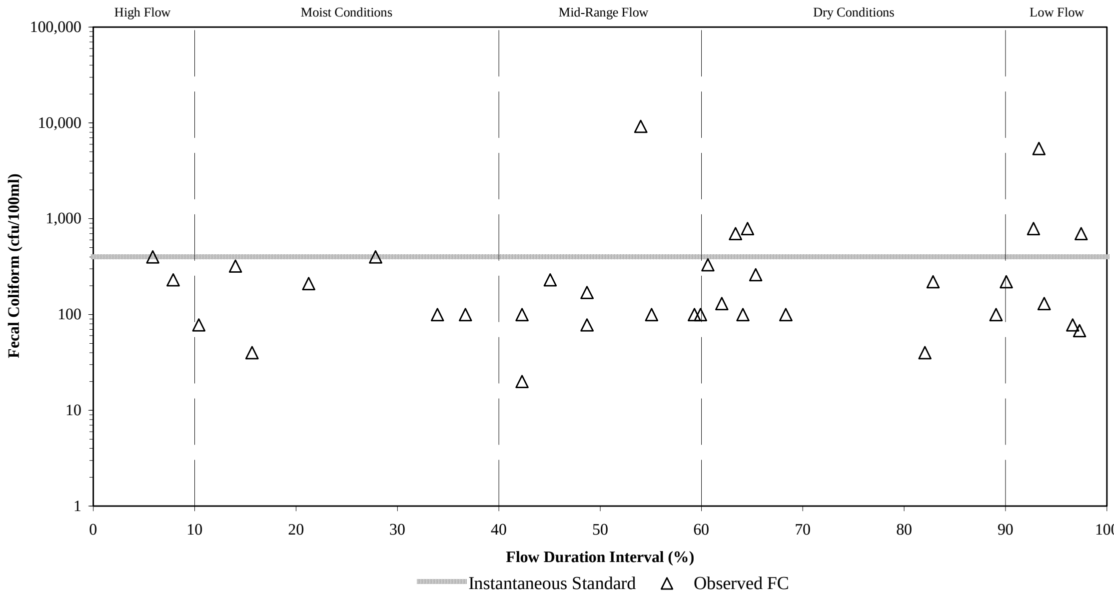

Figure C. 1 **Relationship between fecal coliform concentrations (VADEQ Station 2-BDC000.79) and discharge (USGS Gaging Station #02036500) in the Beaverdam Creek impairment.**

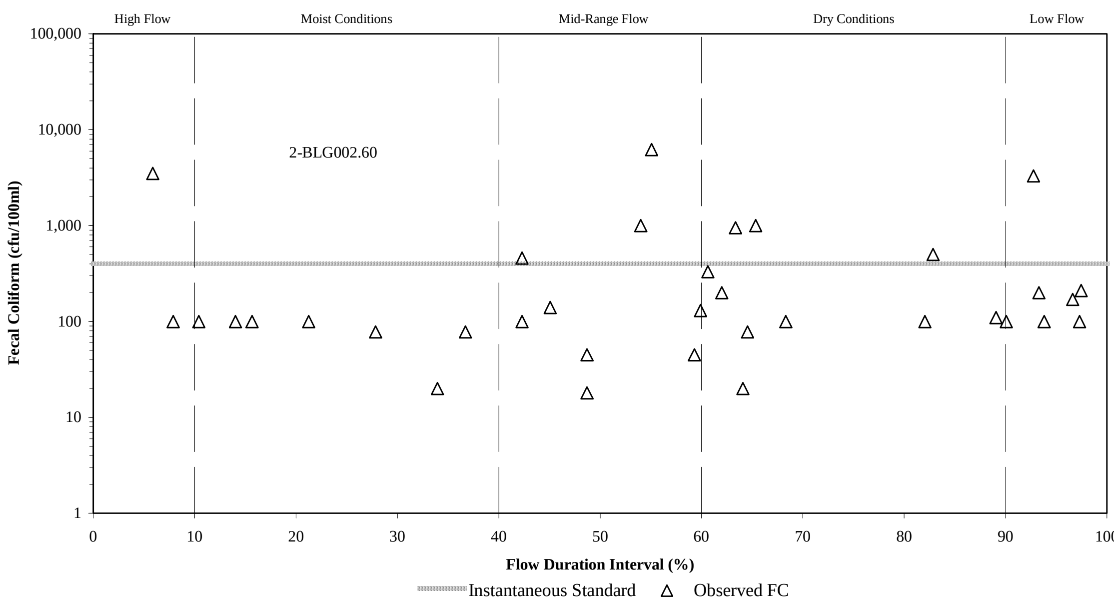

Figure C. 2 **Relationship between fecal coliform concentrations (VADEQ Station 2-BLG002.60) and discharge (USGS Gaging Station #02036500) in the Big Lickinghole Creek impairment.**

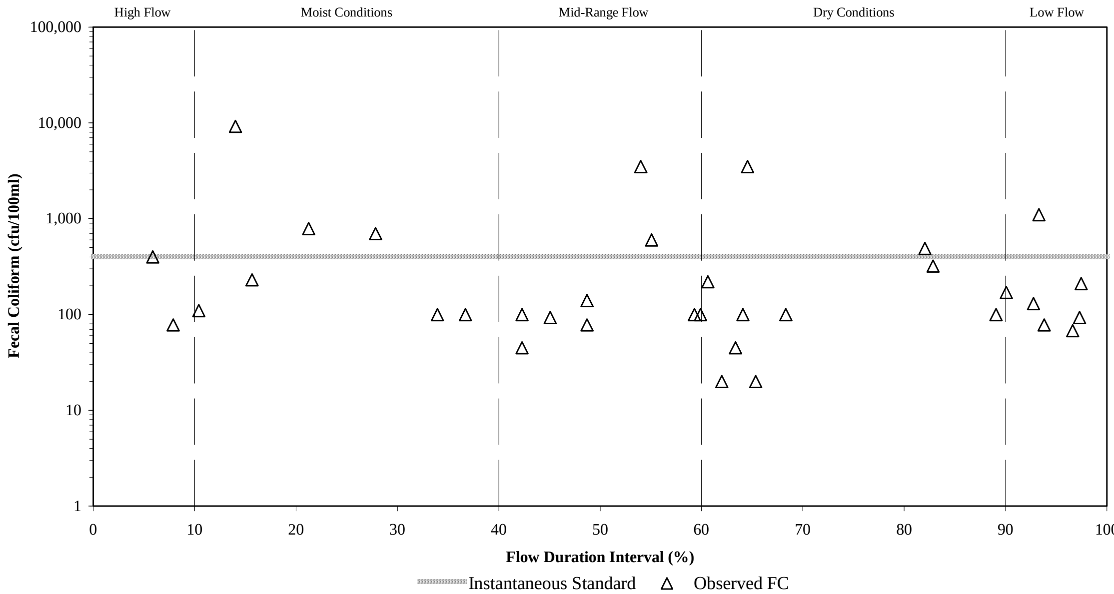

Figure C. 3 Relationship between fecal coliform concentrations (VADEQ Station 2-BYR003.35) and discharge (USGS Gaging Station #02036500) in the Byrd Creek impairment.

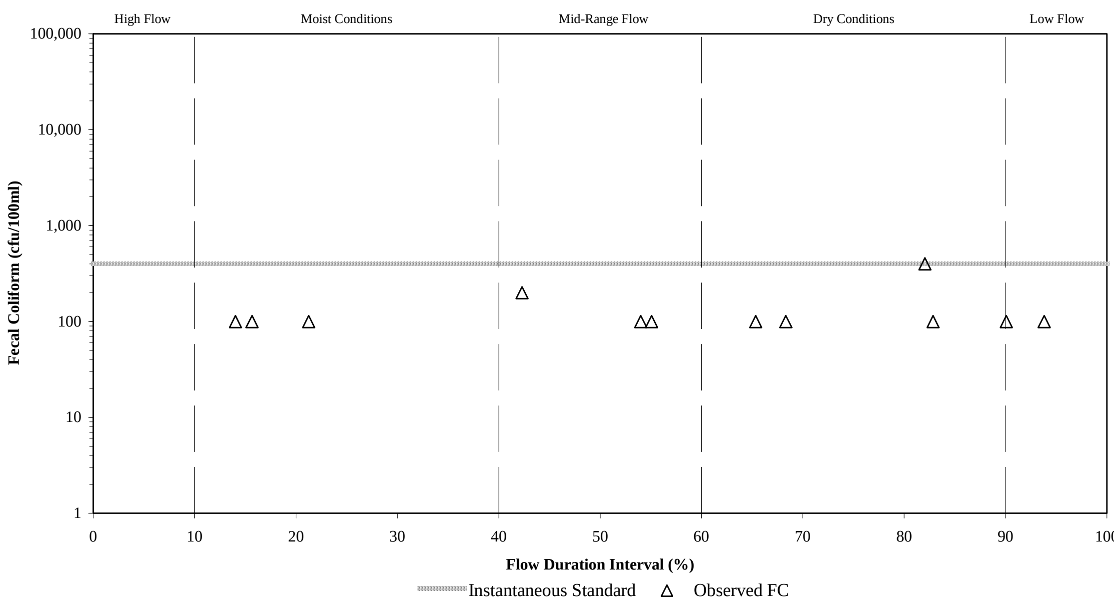

Figure C. 4 Relationship between fecal coliform concentrations (VADEQ Station 2-DCR007.93) and discharge (USGS Gaging Station #02036500) in the Deep Creek impairment.

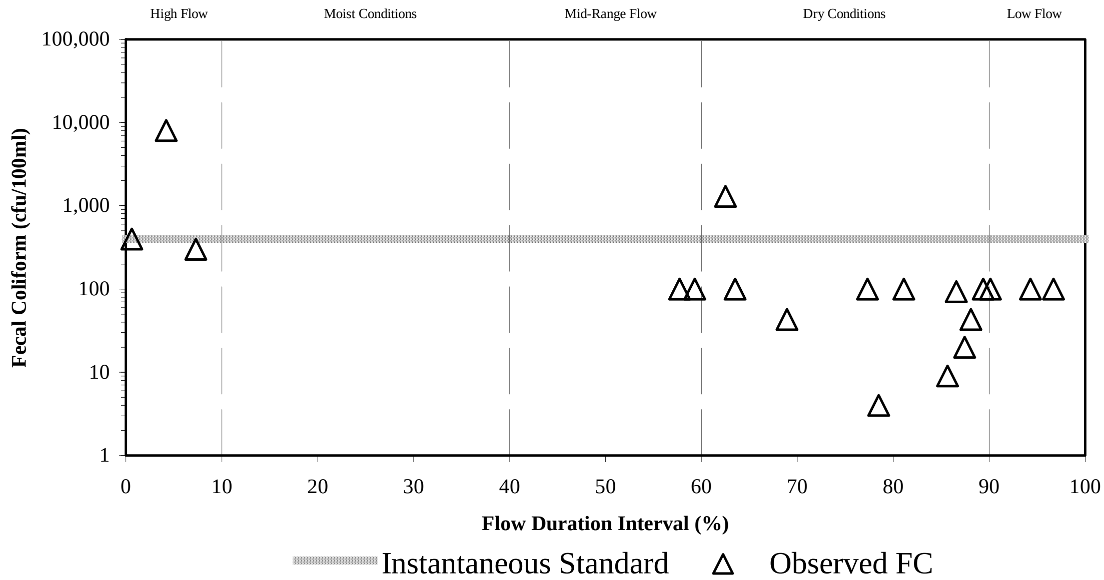

Figure C. 5 Relationship between fecal coliform concentrations (VADEQ Station 2-JMS140.00) and discharge (USGS Gaging Station #02037500) in the James River impairment.

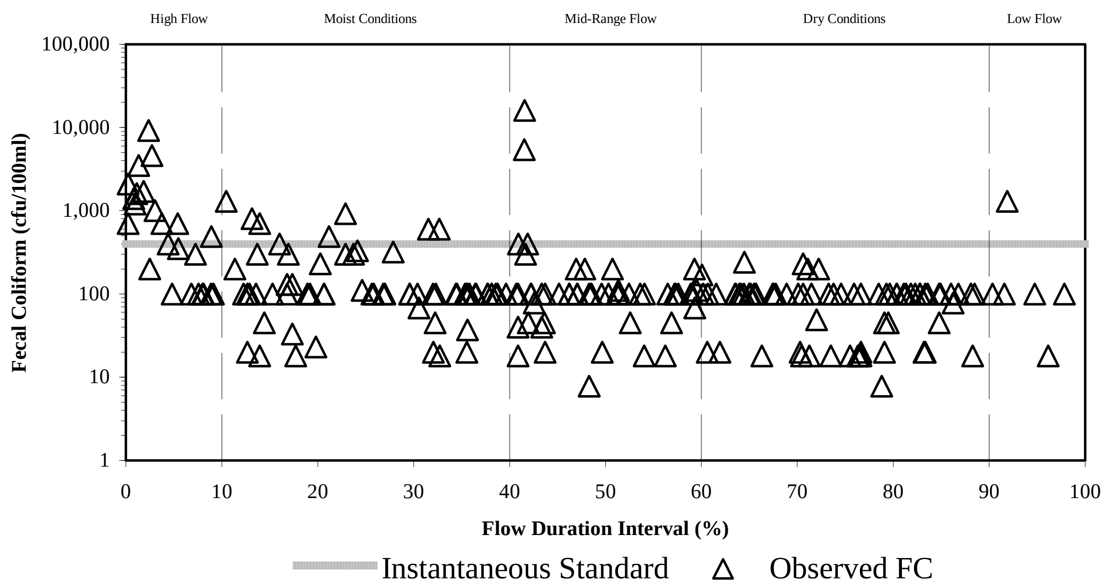

Figure C. 6 Relationship between fecal coliform concentrations (VADEQ Station 2-JMS157.28) and discharge (USGS Gaging Station #02037500) in the James River impairment.

APPENDIX D

Water quality validation plots

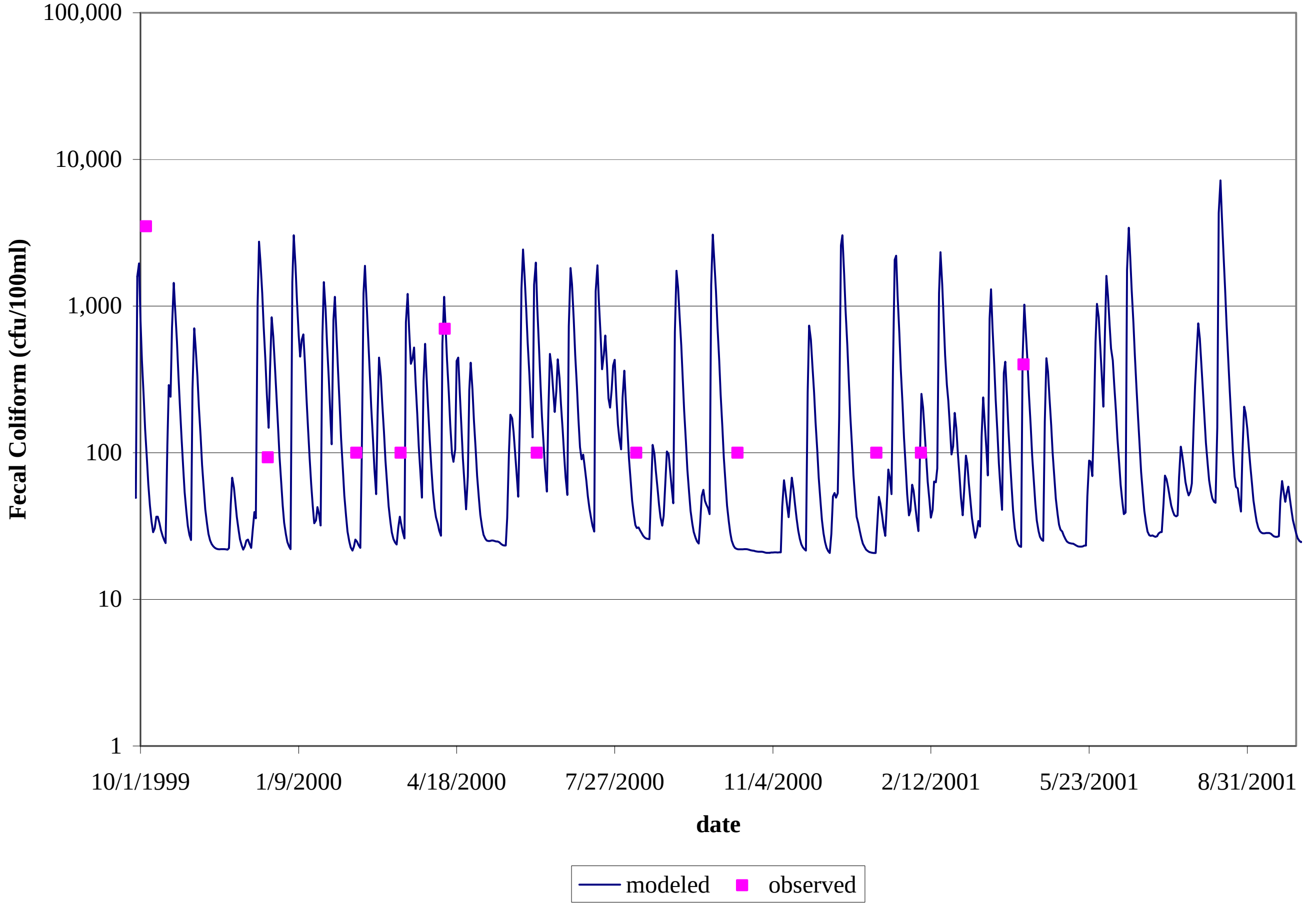

Figure D. 1 Quality validation results for period 10/1/1999 to 9/30/2001 for Byrd Creek, subshed 11 (VADEQ Station 2-BYR003.35).

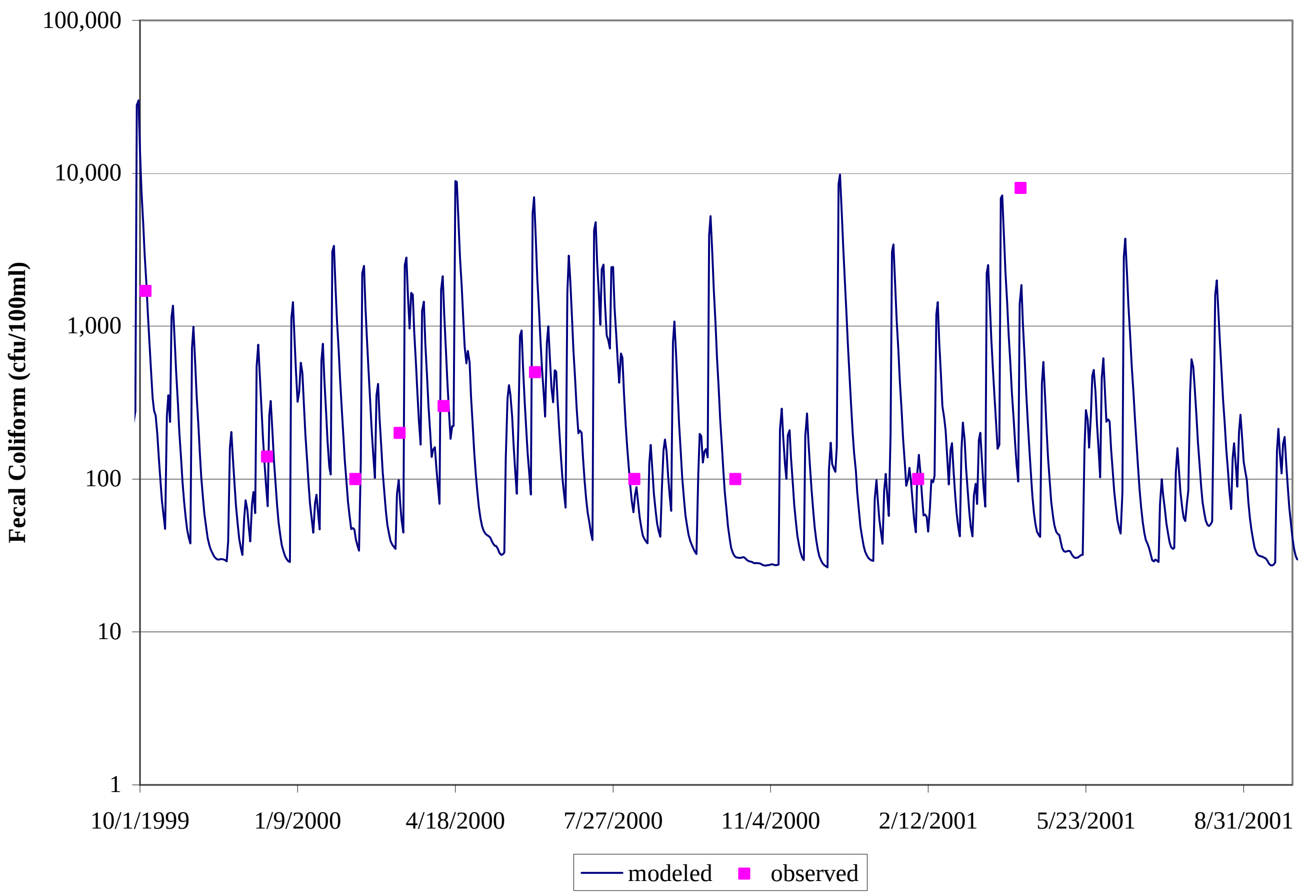

Figure D. 2 Quality validation results for period 10/1/1999 to 9/30/2001 for Big Lickinghole Creek, below the confluence of subshed 14 and subshed 16 (VADEQ Station 2-BLG002.60).

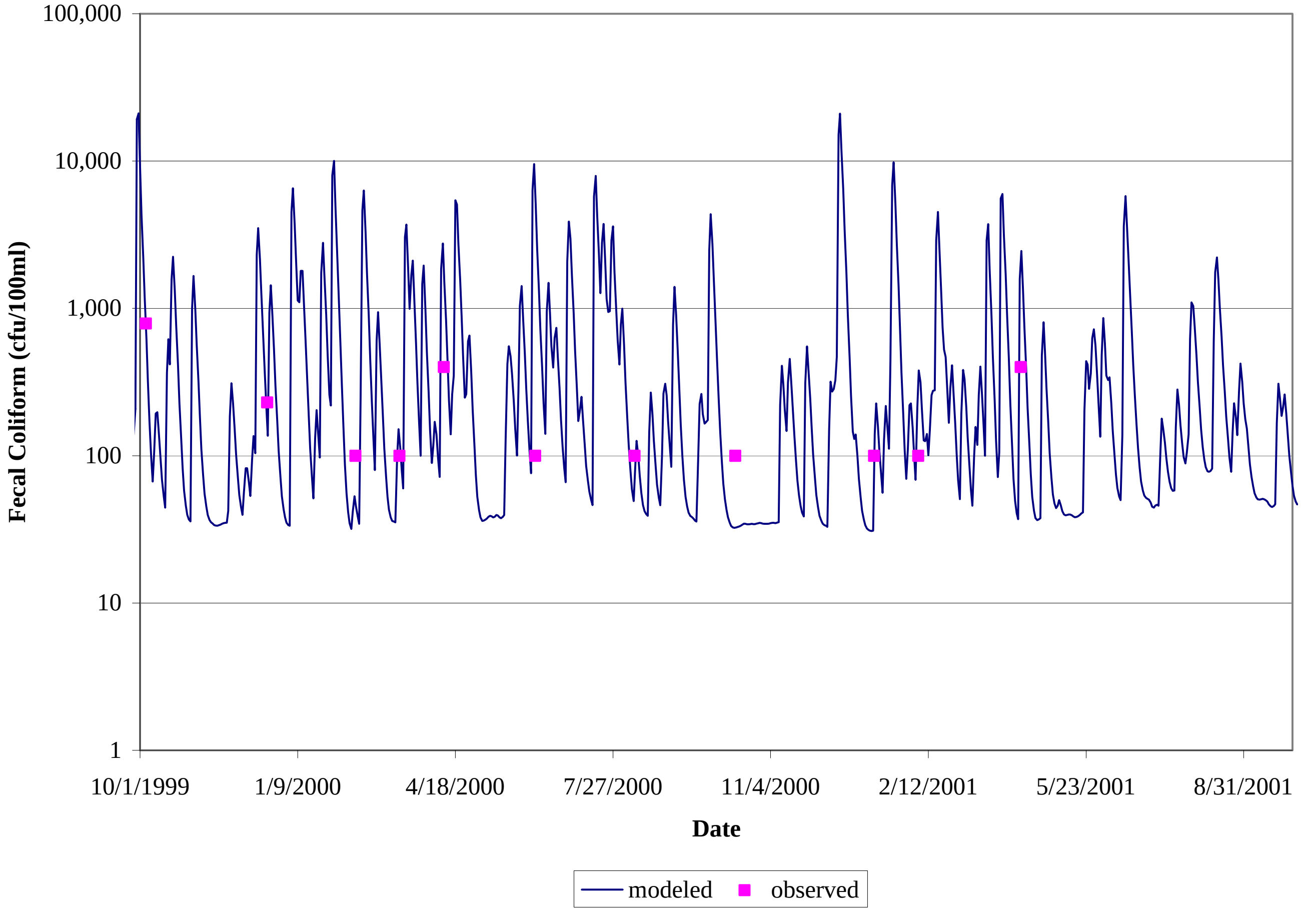

Figure D. 3 **Quality validation results for period 10/1/1999 to 9/30/2001 for Beaverdam Creek, subshed 18 (VADEQ Station2-BDC000.79).**

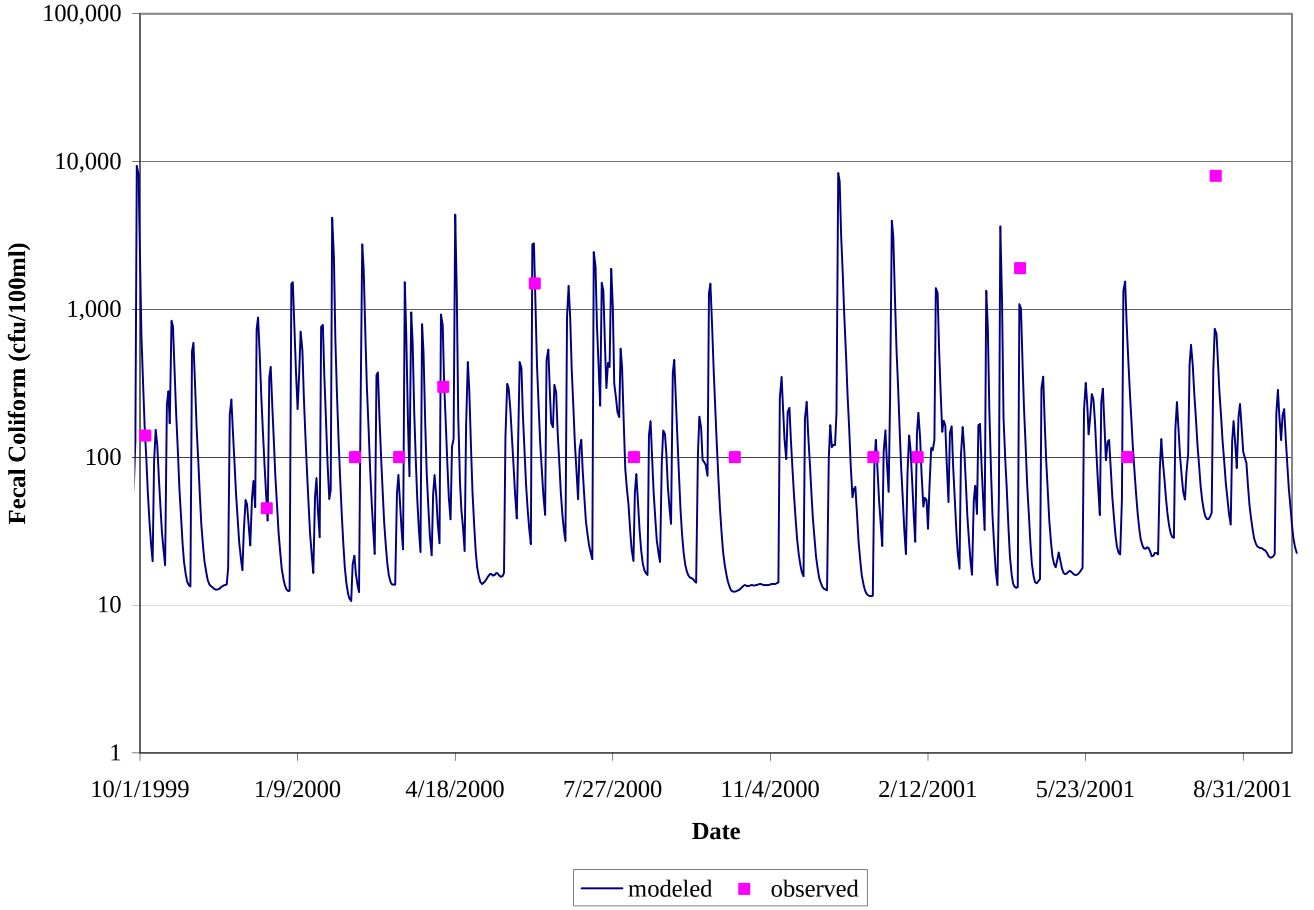

Figure D. 4 Quality validation results for period 10/1/1999 to 9/30/2001 for Fine Creek, subshed 19 (VADEQ Station 2-FIN000.81).

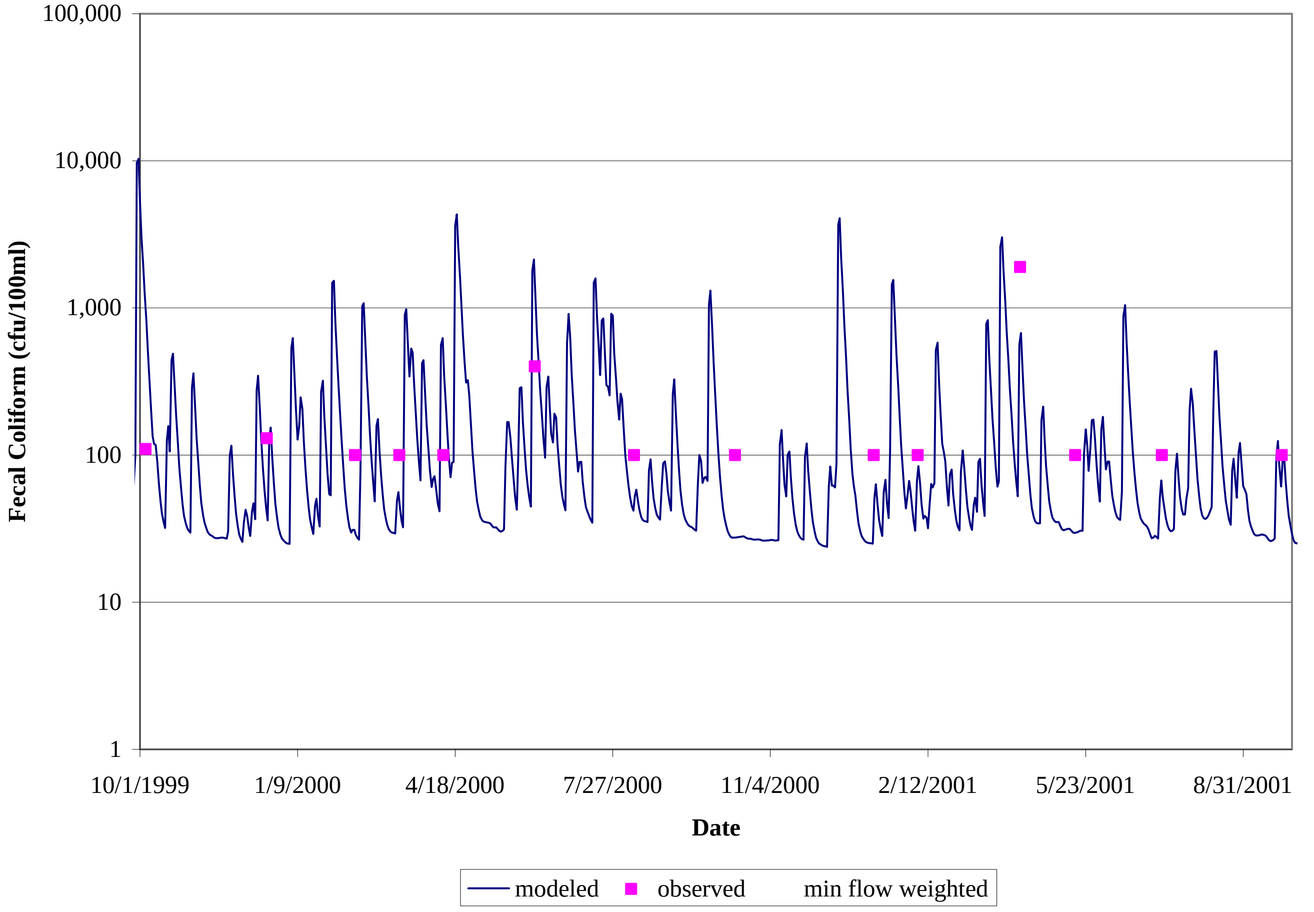

Figure D. 5 Quality validation results for period 10/1/1999 to 9/30/2001 for Deep Creek, below the confluence of subshed 32 and subshed 33 (VADEQ Station 2-DCR003.00).

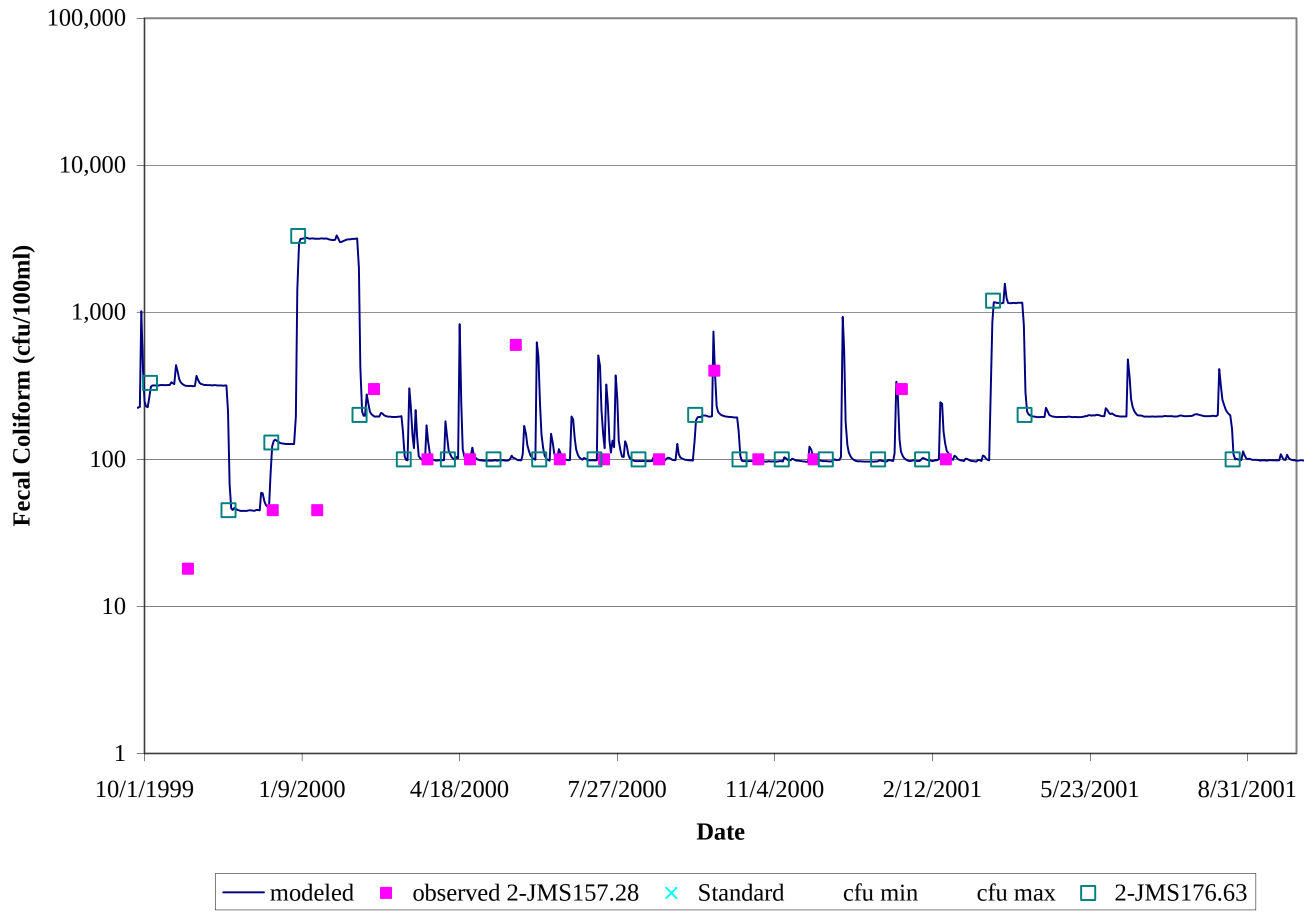

Figure D. 6 Quality validation results for period 10/1/1999 to 9/30/2001 for James River, subshed 2 (VADEQ Station 2JMS157.28).